STUDY ON THE DEHYDRATION PROPERTIES OF OYSTER MUSHROOM (*Pleurotous sajor* caju) UNDER DIFFERENT PRE-TREATMENT CONDITIONS

by

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Study on the dehydration properties of oyster mushroom (*Pleurotous sajor* caju) under different pre-treatment conditions

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Approval Letter

This *dissertation* entitled *Study on the Dehydration Properties of Oyster Mushroom (Pleurotous sajor* caju) *Under Different Pre-treatment Conditions* presented by Anil Kumar Raut has been accepted as the partial fulfillment of the requirements for the B. Tech. in Food Technology.

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Anil Kumar Raut

Abstract

The aim of present work was to study the effect of pretreatments on dehydration characteristics of mushroom. Raw materials (*Pleurotous sajor* caju) were purchased from Simadia VDC of Sunsari district. Mushroom was dried in a hot air oven at 60ºC with different pre-treatments. After dehydration product was analyzed for vitamin C, rehydration ratio, non-enzymatic browning, sensory quality and drying rate.

The mushroom pre-treatments were blanching, sulfiting, blanching and sulfiting and untreated. Blanching was done in water of 85ºC for 3 min while sulfitation was done in 0.3% KMS for 10 minutes.

ANOVA was carried out to study the effect of pretreatments on product characteristics. The effects of pretreatments on rehydration ratio, vitamin-C content and Yield of final product were significant at 5% level of significance. The rehydration ratio varied from 2.65 to 3.12 while vitamin-C content varied from 13.55 to 24.54mg/100g dry matter. Effect of pretreatments varied the yield from 82.55 to 84.02g/kg while color and overall acceptability score varied from 5 to 7.4 and 5.12 to 6.8 respectively. Effects of pretreatments on analyzed parameters were compared by LSD method. Optimization of dehydration process was done on the basis of rehydration ration, color and overall acceptability. The product which was blanched and sulfited was found to be superior. The product had rehydration ration of 3.12 and got score 7.4 and 6.8 for color and overall acceptability.

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KGy	Kilo gray	ppm	parts per million
Hr	Hour	e.g.	Example
KMS	Potassium meta bisulfate	"	Inch
USA	United States of America	mc	moisture content
RH	Relative humidity	wb	wet basis
M	Meter	db	dry basis
Kg	Kilogram	pH	percent of hydrogen ions
°C	Degree centigrade	PPO	polyphenol oxidase
°F	Degree Fahrenheit	LDPE	low density polyethylene
VDC	village development committee	IS	Indian standard
Cm	Centimeter	nm	Nanometer
Mm	Millimeter	ANOVA	Analysis of Variance
spp.	Species	mg	Milligram
%	Percent	i.e.	that is
AIDS	Acquired immune deficiency virus	LSD	least significant difference
NGO	Non-government organizations	P	Potassium
INGO	International NGO	Cl_2	Chlorine
UK	United kingdom	Ca	Calcium
US	United states	K	Kelvin
WVPD	Water vapor pressure difference	AD	After death of Christ
EMC	Equilibrium moisture content	ml	Milliliter
EDTA	ethylene diamine tetraacetic acid	WRM	water in rehydrated material
W_C	Critical moisture content	RR	rehydration ratio
m/s	Meter per second	RC	rehydration coefficient
mg/kg	Milligram per kilogram	a_w	water activity
et al.	et alibi, and others	Fig.	Figure
G	Gram		

Part I

Introduction

1.1 General introduction

Mushrooms are the members of higher fungi belonging to class Basidiomycetes and some are Ascomycetes. They are spore bearing fleshy organ of fungi and characterized by heterotrophic mode of nutrition (Aryal, 2008). Edible mushrooms once called the "food of the gods" and still treated as a garnish or delicacy can be taken regularly as part of the human diet or be treated as healthy food or as functional food (Chang, 199?).

Preservation methods start with the complete analysis and understanding of the whole food chain, including growing, harvesting, processing, packaging, and distribution; thus an integrated approach needs to be applied. It lies at the heart of food science and technology, and it is the main purpose of food processing (Rahman, 2007).

Mushrooms are highly perishable so producers are obliged to sell at lower price at their maximum yielding time. This situation is due to lack of several mushroom processing methods. The agricultural industry produces raw food materials in different sectors. Inadequate management or improper planning in agricultural production can be overcome by avoiding inappropriate areas, times, and amounts of raw food materials as well as by increasing storage life using simple methods of preservation. Value-added food products can give better-quality foods in terms of improved nutritional, functional, convenience, and sensory properties. Consumer demand for healthier and more convenient foods also affects the way food is preserved. Eating should be pleasurable to the consumer, and not boring. People like to eat wide varieties of foods with different tastes and flavors. In food preservation, the important points that need to be considered are (Rahman, 2007):

1) Desired level of quality
2) Preservation length
3) Group for whom the products are preserved.

The quality of fruits and vegetables deteriorates progressively after harvest within short time owing to a series of physical, physiological, and pathological agents the produce is exposed to before reaching a consumer or a processor (Mishra and Gamage, 2007). In recent years, there has been a considerable increase in the demand for high-quality fruits and vegetables, coupled with convenience and safety. Fruits and vegetables are living

organs of plants that undergo biological and biochemical activity even after they are separated from their plants (Perera, 2007). Due to perishable in nature mushroom should be preserved properly to extend its shelf life immediately after harvesting (Kharel and Hashinaga, 2004).

Mushroom, due to its high moisture content (89-92%), it cannot be preserved more than 2 or 3 days at normal temperature. Being a high moisture content produce, its respiration rate is also high, so it require immediate processing. Nowadays mushroom processing techniques such as Canning, individual quick freezing (IQF), vacuum freeze drying (VFD), Drying, vacuum drying, Pickling, Steeping in salt solution, radiation preservation etc. have been developed. These are used on the basis of their merits per se market demand and end use (Anon, 200?).

Mushrooms are rich source of protein, minerals and vitamins. They have good quality protein and are producing the highest quantity of protein per unit area and time from the agricultural waste. Drying is a thermo-physical and physico-chemical process by which the excess moisture from the product is removed. The purpose of dehydration is to enhance storability and minimize packaging and handling cost. Pretreatment, drying temperature, drying time, drying method and moisture content of the product highly influence the final quality. Several drying techniques such as sun-drying, solar drying, hot-air, tray and cabinet drying, fluidized bed drying, vacuum drying, infra-red drying, microwave drying, freeze drying and osmotic dehydration have been used successfully for mushrooms to prolong their self-life and storability. Various pretreatments of mushrooms before drying (washing in water, blanching, sulphiting, steeping in salt solutions) have been attempted to check the browning reaction and enhance the flavor retention and quality of dehydrated mushroom pieces (Chandra and Samsher, 2006).

Under ideal climatic conditions, shelf life of mushrooms is about 10 days, their quality being affected predominantly by storage temperature. The shelf life reduces from 9 days at 2°C to 3 days at 18°C (Lukasse and Polderdijk, 2003). Therefore, cooling the fresh mushrooms can be an alternative way to increase their self life there by increasing their distribution and sale time (Villaescusa and Gil, 2003). For long periods of preservation, the traditionally used method for *Pleurotus* genus mushrooms is the convective drying at 45-65ºC (Pal and Chakraverty, 1997; Arora *et al.*, 2003). Dehydration is a classical method of food preservation, based on the principle that the reductions of the water activity of the

product guarantee the microbiological and physicochemical stability (Krokida *et al.*, 2003). In Nepal research and cultivation of mushroom was initiated since 1974 in mushroom units under Central plant pathology Division, Khumaltar. The division is conducting research on cultivation of two types of mushroom species viz. white button mushroom (*Agaricus bisporus*) and oyster mushroom (*pleurotous sajor* caju) (Thapa,1995). Recent years the processing and value addition work is solely under the control of food research unit at National agriculture research council (NARC).

Since, mushroom is a perishable produce, it is forced to sell in low price thus preservation in peak growing season is must to gain profit in lean season. The production is easy, requires small land but the produce being highly perishable; development of processed mushroom is necessary to lift up farmers economic gain and livelihood.

The mushrooms of the *Pleurotus* genus are more delicate and sensitive than the *Agaricus* genus and they start deteriorating immediately within one day after the harvest. Once deteriorated, these fruiting bodies can cause severe gastrointestinal discomfort.

Generally, cultivated mushrooms should play a greater role in the endeavor to increase food protein. This is especially true in developing countries, since growth substrates for mushrooms are basically agricultural and industrial discards that are inedible for humans (Chang and Miles, 1984).

In 1997, Asia contributed 74.4% of the total world mushroom tonnage, Europe, 16.3%, North America, 7.0%, and Africa and Latin America shares less than 1%. The world production of mushroom had increased from 1060 to 12250 thousand tons from 1978 to 2006 (Chang 1999) and (CEFA, n.a.). In Nepal, mushroom growers grow 2000 to 3000 kg of mushroom per day during summer season (Manandhar, 2004).

1.2 Statement of the problem

Like fruits and vegetables mushroom are highly perishable (Bhal, 1994). Mushroom contains 91.1% moisture content. It can be preserved for about 3-5 days at temperature 0-5ºC at 85-95% relative humidity (Potter, 1987). Due to its high moisture and high respiration rate the harvested mushroom needs immediate processing and/or marketing. The demand and supply is never the same, thus to prevent such glut in the fresh market it is necessary to preserve them. Mushroom can be preserved by different method such as Dehydration, Canning, Bottling, Freeze drying, Pickling, Irradiation etc. (Bhal, 1994).

Nowadays production of mushroom is increasing rapidly and is being economically advantageous for producer. Cultivation of the mushroom has proved its beneficial value for consumer. Of the different processing methods drying of mushroom can be the effective method of processing for small scale as well as large scale mushroom grower due to ease of processing and cost effectiveness. Dried mushroom can be of good market valued product as it is easy to reconstitute and contains considerable amount of nutrients.

After drying mushroom, it can be sold in off-season in reasonable price. Large excess of mushroom can be utilized preventing loss .The dried mushroom can also be utilized for other value added products such as soup, soup base, mushroom paste etc.

1.3 Objective of the study

1.3.1 General objective

The overall objective of this study was to study the dehydration characteristics and rehydration properties of Oyster mushroom (*Pleurotous sajor* caju*)* under different pre-treatments conditions.

1.3.2 Specific objective

The specific objectives of the study are as follows

1) To study the drying characteristic of mushroom at 60ºC in a cabinet dryer.
2) To compare the drying characteristics of fresh, blanched, sulfited and blanched and sulfited mushroom.
3) To compare the rehydration properties of dried mushroom.
4) To study the sensory quality of the dried mushroom.
5) To optimize the dehydration process.

1.4 Hypothesis of the study

The study is being carried to find appropriate pre-treatment method for the dehydration of oyster mushroom. The different parameters under study are pre-treatments, its effect on the drying characteristics, rehydration properties and several sensory characteristics.

The hypothesis of the study is the best pretreatment would be blanching followed by sulfiting. On the basis of this hypothesis the null hypothesis can be set as the dehydration time will be least for that treatment and the product quality with respect to color,

rehydration properties, vitamin ‘C’ retention and overall acceptability will be best in contrast to fresh, blanched or sulfited.

1.5 Limitation of the study

1) The rehydration characteristics and sorption behavior were not studied due to unavailability of the lab instruments.
2) The shelf life of the product was not studied due to lack of time.
3) The microbiology of the product was not studied.
4) The drying temperature was not varied.
5) The sulfitation treatment was not optimized.

Part II

Literature review

2.1 Mushroom

Mushroom, an edible fungus, has been used as a food item since ancient times. It grows on decomposed organic matter and produce edible portion above the surface of the substrate. Out of large varieties of mushrooms, less than 25 species are accepted as food and few of them have assumed commercial significance (Angle & Tamhane, 1974).

Mushroom is a delicate fleshy fungus having high nutritional value. Mushrooms are saprophyte belonging to the lower plant group. Wild species often grow in the humus deposing during the rainy season being a temperature optimum (Hayes and Nair, 1974).

Mushrooms are a special group of macroscopic fungi that lack chlorophyll and therefore, need substrate for their own absorptive nutrition. Mushrooms produce enzymes that degrade complex organic matter and absorb the soluble substances (Chang and Miles, 1989).

According to Srivastava and Kumar (2002), mushrooms are a rich source of proteins, vitamins and minerals. Their low content of carbohydrate and fat makes them an ideal food for diabetics and persons who wish to shed excess fat. They are also a good source of energy; about 454 g of fresh mushroom provides 120 K-calories.

Also according to Pal and Chakraverty (1997), mushroom produces high quality and quantity protein from worthless agro waste, which is superior to other plant proteins. Fresh mushroom is soft textured and highly perishable and must be either consumed or processed immediately after harvest (Sahbaz *et al.*, 2000; Giri and Prasad, 1997). Various physiological and morphological changes occur after harvest, which make these mushrooms unacceptable for consumption. Hence, they should be traded mostly in processed form in the world market (Giri and Prasad, 2007).

2.2 Historical background

The word mushroom is thought to be derived from the French word 'mousseron', 'mouse', or 'moss'. In Nepal it is known as 'Chyau' in Nepali while it is known by the name of 'kavak' or 'chhatrak' in Sanskrit (Adhikari, 2000). While in India, it is known as'khumbi' or 'kukurmutta' in Hindi (IFT, 1995).

Though mushroom is known to be consumed for time immortal by human beings, it is very difficult to know that when the mushroom consumption was started. Egyptians record legend showing belief that mushrooms were the plant of immortality and they prolonged the life and head aphrodisiac quality. This led Julius Caesar to issue and edict forbidding any of his troops other than captain of cuhorts to eat the plant. Epicures of Rome and the Royalty of France and Britain permitted only the courts and palaces to serve them. In addition, civilizations from many parts of the world, Central America, Mexico, China, Siberia, Greece and Russia all practiced mushroom ritual (Hayes and Nair, 1984). Past Roman writer Muselies said, “it is easy to reject gold or silver but difficult to reject mushroom plate without touch”. Also Roman king Niro decided to give huge prize for a poem of the mushroom.

The oldest archaeological of mushroom use discovered so far is probably a Tassili image from a cave which dates back 3,500 years before the birth of Christ. Mushrooms with electrified auras are depicted outlining a dancing shaman. The spiritual interpretation of the image transcends time and is obvious. No wonder that word 'bemushroomed' has evolved to reflect the devout mushroom lover's state of mind (Paul, 1993).

There are different views regarding the origin of the term 'mushroom'. In Latin 'fungi' means to flourish. It was a term which was used to refer to mushroom and to excrescencies from the ground or from trees. In Greek the term 'mushroom' was derived from the word 'sphoggos' which meant 'Spongo' and referred to the sponge like structure of some of the species (Bhal, 1994).

The method of cultivation was recorded as early as 300 BC and then international cultivation was started as early as 600 AD in China. Artificial cultivation of mushrooms was initiated in France around 1650 AD and rapidly spread to entire Europe continent as a garden crop. In the early years of 19^{th} century, mushrooms were commercially cultivated inside the caves in France. According to experts, the mushroom consumption was first tried out by the Chinese. However, during the process of identifying the edible ones, hundreds of people died by the consumption of poisonous mushrooms (IFT, 1995).

In Nepal first exploration and collection of Nepalese fungi was carried out by J.D. Hooker (1848-1854) in eastern Nepal (Adhikari, 2000). In Nepal mushroom cultivation was initiated by the Division of Plant Pathology, Nepal Agricultural Research Council (NARC) in 1974. The growing technology for white button mushroom was developed

during that early period and extended to general farmers starting in 1977. It utilized the synthetic media of paddy straw, which is harvested twice a year in Kathmandu. Of course, a few farmers grew mushrooms before the introduction of the technology but the number of button mushroom growers has increased year after year thanks to the spread of the technology.

The growing technology to grow Oyster mushroom using chopped straw packets was introduced to the farmers in 1984, and since then mushroom cultivation has become more popular among farmers. These two kinds of mushroom cultivation systems have been employed by farmers in about 25 districts within Nepal. The Centre for Agricultural Technology (CAT) has recently introduced straw mushroom (*Volvoriella volvacea*) cultivation in the Terai districts and shiitake in the hill districts and has been instructing farmers how to grow them since 2001 (Manandhar, 2004).

2.3 Botany of mushroom

2.3.1 Vegetative structure

The vegetative plant body of mushroom is mycelium which is found under the soil, mycelium is of two types they are primary and secondary mycelium.

The primary mycelium is formed by the germination of basidiospore and is of short lived in nature. It is haploid and consists of much branched, loosely tangled mass of hyphae which are septate and hyaline. The cells of these hyphae are uninucleated and contain oil globules, vacuoles and thin cytoplasm. Later the primary mycelium becomes binucleate by somatogamy and results the secondary mycelium. The secondary mycelium consists of filamentous, septate and much branched hyphae, which spread through the substratum and persists for many years. Minute pores called dolipres perforate the septa of these primary and secondary hyphae. These pores establish intercellular communication. Some of the secondary mycelium is interwoven into the thick rope like strands and compact mass of hyphael strands known as rhizomorphs. Rhizomorphs form the fruting bodies or sporophores above the ground (Keshari *et al.*, 2004).

2.3.2 Fruiting body

Fruiting bodies are formed when sufficient food is absorbed by the mycelium. They are pin-head size initially. In suitable temperature and moist condition, they grow and appear

in the form of small rounded bodies, known as buttons. These buttons grow outwards into the air. They are commonly called mushroom or basidiocarp. Each mushroom consists of a short fleshy stalk called stipe. It is made up of closely packed colorless hyphae (Keshari *et al.*, 2004).

The basiodiocarp is attached to a mycelium just beneath the substratum, which helps to absorb nutrients. Stipe is crowned with a large and circular umbrella like a head called pileus. Under the surface of the pileus a gill cavity is present. In this cavity, a large number of thin, vertical plate like structure which run out towards the edge of pileus like the radiating bar of a wheel are called gills or lamellae. The gills vary in number from 300 to 600 in each pileus. In button stage, a thin delicate membranous tissue connects the pileus and stipe and is known as velum. The velum fails to keep pace with the enlarging pileus and elongating stipe and thus breaks, forming a ring like structure (annulus) around the upper part of the stipe as shown in Fig. 2.1.(Keshari *et al.*, 2004).

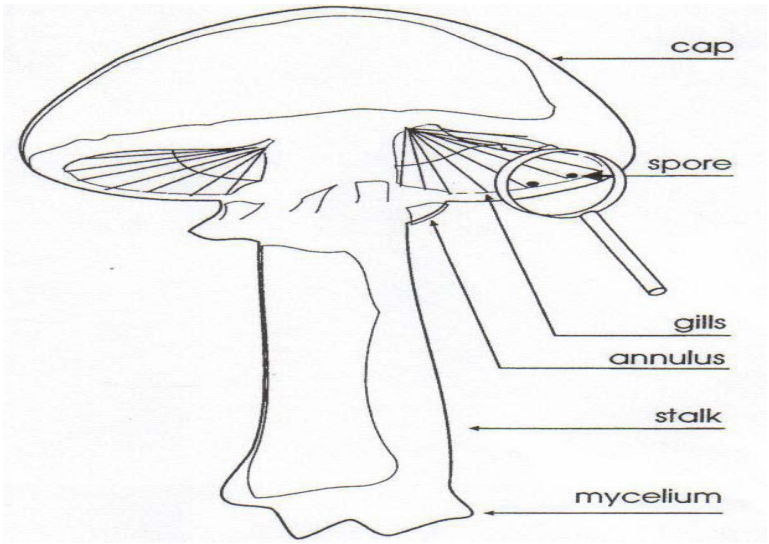

Fig. 2.1 Mushroom showing its different parts

2.4 Morphological and physical characteristics

2.4.1 Morphological features

Mushrooms are special group of macroscopic fungi. They lack chlorophyll and therefore, need a substrate for nutrition. Mushrooms produce enzymes that degrade complex organic matter and absorb the soluble substances (Chang and Miles, 1989). A typical button mushroom has mainly three parts namely, Cap (pileus), Gills and Stalk or Stipe. It may or may not have a ring called ‘annulus’ below the cap, and a basal cap or volva (Nichols, 1985). The illustration is shown in Fig. 2.1.

2.4.2 Physical features

According to Lal and Sharma (1995), the typical features of fresh mushroom are veil closed; gills visible, upper surface of cap opened and stem are elongated. Beelman (1988) observed that consumers prefer clean, smooth surface with crisp and tender structure. These characters are associated with freshness of mushroom.

The mushroom has a broad, fan or Oyster-shaped cap spanning 5–25 cm; natural specimens range from white to gray or tan to dark-brown; the margin is enrolled when young, and is smooth and often somewhat lobed or wavy. The flesh is white, firm, and varies in thickness due to stipe arrangement. The gills of the mushroom are white to cream, and descend on the stalk if present. If so, the stipe is off-center with a lateral attachment to wood. The spore print of the mushroom is white to lilac-gray, and best viewed on dark background. The mushroom's stipe is often absent. (Wikipedia, 2010)

2.4.2.1 Color

The Oyster mushroom is creamy to white in color with no any mark or discoloration on its cap while the stalk is also white in color with or without any mark or discoloration (Manandhar, 2004).

Fresh white button mushrooms are white or light buff without any dark mark on either cap or stem (Lal and Sharma, 1995).

2.4.2.2 Size

Average size of mushroom has been reported to be of 25 to 45 mm in diameter, 3 to 10 mm stipe and 11.5± 1.8g in weight (Burton *et al.,* 1987 and Riva *et al.,* 1991). Average size for export and domestic fresh market mushroom is generally 20 to 40 mm buttons with velum intact (Dang *et al.,* 1978).

2.5 Varieties of mushroom

2.5.1 Edible varieties

There are around 38,000 mushroom varieties known to exist, however about 100 of them are considered to be edible. Of the edible varieties, the most popular ones are the *Agaricus bisporus* (the European or white button mushroom), *Lentinus edodus (Shitake) or* Japanese mushroom, P*leurotus* spp like *Pleurotus ostreaus* (American Oyster mushroom)and the

Pleurotus sajor caju (*dhingri* or Indian Oyster mushroom), *Volvariella volvacae* (the Chinese or paddy straw mushroom) (IFT, 1995).

2.5.2 Inedible varieties

Among thousands of mushroom species fewer than a hundred are toxic. Most fungal toxins cause mild or moderate poisoning. It is, however, the ingestion of a few species of extremely poisonous fungi that define the medical dimension of the problem. Mushroom poisoning is mostly accidental and the result of a mix-up between edible and toxic fungi, but intentional ingestion of psychotropic (magic) mushrooms is also a problem **(**Beck and Helander, 1998).

The most dreaded poisonings are those caused by cytotoxic agents e.g. amatoxins in death cap and destroying angel (severe gastroenteritis and liver damage) or orellanine in *Cortinarius* spp. (kidney damage). Dramatic, but rarely lethal, effects are caused by fungi-holding neurotoxins like muscarine (*Clitocybe* and *Inocybe* spp.), psilocybin (*Psilocybe* and *Panaeolus* spp., 'magic' mushrooms), isoxazoles (fly agaric and panther cap) and gyromitrin (false morels). Many poisonous species cause gastroenteritis only (Resinsky and Besl, 1990).

2.6 Cultivation method of Oyster mushroom

Firstly, the culture of *pleurotus* spp. is activated in potato dextrose agar (PDA) or similar suitable media and mixed with sterilized wheat, barley, horsegram powder and incubated for mycellial growth. Later on, rice or wheat straw chopped to 2" length is soaked overnight in tap-water and then excess water is drained out. Sterilized and the wet straw (75% moisture content) is mixed with 10% spawn (culture) and coarse horsegram powder (1%) and stuffed into perforated polythene bags. After mycellial growth in outer sides, the polythene is to be removed, exposing the pinheads to the ambient atmosphere which grow to maximum size in next three days (Aneja, 1993).

According to Aneja, (1993), cultivation of mushroom is done in line with Pal and Thapa (1979) method. Spawn was run at maximum 20-25°C for 2-3 weeks till the substrate is covered with white mycelium. The polythene bag is carefully removed from the substrate and blocks were kept on shelf. The first flush of mushroom could be harvested 7-10 days after opening the polythene bags. Twice a day watering is must to keep the block moist and to maintain the room humidity. The next harvesting can be done after a week's gap.

2.7 Proximate composition of mushroom

With respect to proximate composition, there are wide variations in their values as reported by different workers for the same species and for different species of mushrooms. Table 2.1 shows the proximate and chemical composition of Oyster mushroom.

Table 2.1 The composition of mature fruit bodies of *Pleurotus sajor caju*

Parameters	Fresh weight (% wb)
Moisture	90.8
Dry matter	9.2
Crude fiber	1.1
Crude protein	2.78
Crude fat	0.35- 0.65
Starch	0.02
Sucrose	0.6
Glucose	1.45
Ash	1.1
Carbohydrate	5.51
vitamin C	15.6
Energy value	24.40 Kcal

(Aneja, 2003)

2.7.1 Moisture

Pruthi *et al.,* (1984) reported moisture content between 86.5 to 92.0% in fresh mushroom. The average moisture content of mushrooms is about 90%. Deviations from this value have been reported whenever there is a variation in the culturing conditions such as water content of the bed, temperature and relative humidity of the chamber (Rajarathnam and Bano, 1988).

Rai (1990) showed that moisture content of mushroom was affected by the stage of growth, environmental conditions around the fruit body sampled, watering regime and post harvest storage before analysis.

2.7.2 Protein

Mushroom proteins are comparable to muscle proteins in nutritive value. In the context of world protein shortage, the Food and Agriculture Organization (FAO) of the United Nations has recommended mushroom as supplementary food item to the growing population of the developing countries, which are based mainly on cereal diet (Hayes and Haddad, 1976). The comparison of digestibility of mushroom protein with other food is tabulated in Table 2.2

Agaricus bisporus contains 2.9 to 3.9% protein on wb and 20-40% on db (Pruthi *et al.*, 1984), (Tomar, 1998) and (Sethi *et al.*, 1991). Tyagi (2004) found that fresh *Agaricus* contained 3.85% protein.

Table 2.2 Protein digestibility of the different food products

Food products	Total protein % (db)	Digestible protein %	Digestibility %
Meat	83.7	82.8	98.9
Mushroom	51.9	45.9	88.5
Spinach	34.5	25.0	72.5
Legumes	26.3	23.4	89.0
Rye bread	10.7	9.0	84.1
Potatoes	8.0	7.3	91.2

(Anderson and Fellers, 1942)

2.7.3 Fat

Mushroom is a low fat food (Bano and Rajarathnam, 1986). Low fat content, high fiber content and absence of cholesterol makes mushrooms dietician's choice for heart patients. *Agaricus* contains 0.18 to 0.39% fat on wb (Khaddar *et al.*, 1999).

Rai (1990) reported lower range of fat content (0.10 to 0.19% on wb) in *Pleurotus* species. Bano and Rajarathnam (1986) reported 1.8% fat in *Agaricus bisporus* and 1.0 to 9.4% in *Pleurotus* species on db.

Li and Chang (1982) observed that crude fat increases as the paddy straw mushroom matures and constitutes about 5% of the dry weight of fully matured fruit bodies. It appears that the variation in fat content is because of the difference in species, growing conditions and the maturity at the harvesting time.

2.7.4 Carbohydrates

Bano and Rajarathnam (1982) reported that*Pleurotus florida* contained 58% carbohydrates on db.According to Tyagi (2004) fresh *Pleurotus* contained 4.72% total carbohydrates and fresh *Agaricus* contained 3.63%.

According to Ajlouni *et al.* (1992), higher amount of carbohydrates (28% on db) are present in lower stipes; gills contained 10% carbohydrates and upper stipes contained 19% carbohydrates. Since, mannitol is the main respiratory substrate; they found removal of stipe to result in increased shelf life of mushrooms.

2.7.5 Fiber

Fiber content of mushrooms has been reported to be low (0.9 to 1.17% on wb). These values did not change much till maturity. However, its level showed a sharp increase on attaining maturity. Some researchers (Tomar, 1998 and chaudhary, 2000) found slightly lower range of crude fiber (0.34 to 1.126%). Pruthi *et al.*, (1984) reported 16.2% fiber content on db.

2.7.6 Minerals

Mushrooms supply a number of valuable minerals especially potassium and iron. Minerals like calcium, phosphorus, sodium and copper are also present. Mineral content varies from species to species depending upon cultivated substrate. Mushrooms have higher potassium to sodium ratio (Tomar, 1998).

Chang and Miles (1989) reported 8- 10% ash on db in *Agaricus bisporus* Potassium constituted 45% of total ash content followed by phosphorus, sodium, magnesium and calcium which together constituted about 56 to 70% of total ash content.

2.7.7 Vitamins

Mushrooms are good source of water soluble vitamins, i.e. vitamins of B and C group, but they are relatively poor in fat soluble vitamins. They are relatively good source of vitamin B complex particularly thiamine, riboflavin, niacin, biotin and pantothenic acid. According to FAO (2006) report mushrooms contain 2.5 mg/100 g ascorbic acid on wb whereas others (Tomar, 1998) have found a higher value (5.69 to 8.69 mg/100 g).

Canning and drying resulted in 50-60% loss of vitamins (Sethi and Anand, 1984) in mushroom. The authors also reported wide variation in vitamin C content of different species of mushrooms.

2.7.8 Enzymes

Mechanical injury to the tissues during handling, slicing and washing results in rapid browning of tissues. Polyphenol oxidase (PPO) is the main enzyme responsible for this change of color. The simplest method of inactivating PPO is to apply heat (Ponting, 1960). Mushroom enzymes can be inactivated by use of chemicals, lowering pH etc. (Golan-Goldhirsh and Whitaker, 1984).

To increase the shelf life of fresh mushroom, it is necessary to prevent transpiration, decrease the rate of respiration, prevent exposure to atmospheric oxygen, and overcome PPO activity and prevent polymerization of oxidized phenols into melanoidin pigments (Rajarathnam and Bano, 1988).

2.8 Nutritional value of mushroom

Mushrooms are consumed in a variety of ways because of their delicious flavor. Experts have realized and appreciated the food value of mushroom because of the low calorific value and very high content of protein, vitamins, and minerals. Normally mushrooms contain from 20-40% proteins on dry basis and thus surpass many foods, in terms of protein content. The proteins of mushroom are of high quality and rich in various amino acids (Crisian and sands, 1978).

Crisian and sands (1978) have reported that mushrooms contain more proteins than other vegetables. Even the available vegetables proteins up to 70-90% in fresh mushroom can be digested. Mushroom have low carbohydrate content, no cholesterol and are almost fat free (0.2g/100g). Therefore, they form an important constituent for a balanced diet.

According to FAO (2006), mushrooms are edible fungi of commercial importance and their cultivation and consumption have increased substantially due to their nutritional value, delicacy and flavor. It is rich in vitamins C, D, B, and Mg, P, Ca, dietary fibers and amino acids. Another important ingredient of mushroom is the polysaccharide compound beta-glucan, which enhances cellular immune function. Mushroom protein can serve as food contributing protein in developing countries, where the population mainly depends on

cereal based foods. The Oyster mushrooms are rich in protein, minerals, devoid of starch or low in calories and carbohydrates. These are ideal food for diabetic and heart patient and those who do not want to put on weight (FAO, 1970). The chemical composition of Oyster mushroom (*Pleurotus sajor* caju) is shown in Table 2.1.

2.9 Medicinal value of mushroom

With regards to health benefits and medicinal value, edible fungi produce secondary metabolites, which are biologically active. These secondary metabolites get stored in the fruit bodies of the edible fungi which possesses various therapeutic properties. *Lentinuts edodes* has been shown to have anti-tumor, anti-viral, and hypolipidemic agents (Moore *et al.*, 1985). The hypolipidemic and the hypocholesterolemic properties are due to eritadiene (2,3 dihydroxy-4-9 adenyl) and butyric acid. The anti-tumor properties are due to the polysaccharides lentinans and emitanin (Chihara, *et al.*, 1970).

In addition to anti-tumor, anti-cholesterol, and anti-thromobic effects of mushrooms, *shiitake* mushroom can help in preventing high blood pressure, atherosclerosis, kidney, ailments, diabetes, cataract, neuralgia, gallstone, numbness of hand and feet, hemorrhoids and also improves sexual powers (Mori, 1974). Protein containing polysaccharides containing anti-tumor activity were reported from *Pleurotus sajor caju* by Zhaung *et al.*, (1993).

It is quite useful to prevent high blood pressure, diabetes, bleeding, breast and lungs disease, jaundice, intestinal worm infections, throat diseases. It also contains lecithin which helps to keep the cholesterol down and enzyme trypsin which is valuable aid to digestion. Clinical extracts of L-edodes which shows anti-AIDS property are also being carried out in USA. Additionally it has been found that the mushroom contain retine, so can prevent the growth of tumor and cancer both of which are caused by the lack of retine generally (IFT, 1995).

Mushrooms are an excellent source of potassium, a mineral that helps lower elevated blood pressure and reduces the risk of stroke. One medium portabella mushroom has even more potassium than a banana or a glass of orange juice. One serving of mushrooms also provides about 20 to 40% of the daily value of copper, a mineral that has cardioprotective properties (Craig, 2003).

2.10 Production and consumption pattern of mushroom

Nepal is very rich in wild mushroom. Large varieties of mushroom are found in the forest due to varied climatic conditions and the topography of the country. Nepalese in general are habituated to eat mushroom and occasional poisoning occurs. Introduction of mushroom cultivation was done by the Division of plant pathology, Khumaltar since 1974. However, only three types of mushroom viz. *Agaricus, Pleurotus,* and *Volvariella* have been grown in Nepal (Singh, 1998).

A large number of mushrooms grow widely in Nepal under different climatic condition. So far, about 600 species of mushroom have been recorded but a lot of work still needs to be done in this regard. Among the valuable wild mushroom *Morchella, Catherella, Boletus, and Tricholoma* have been found in different districts (like Jumla, Humla, Rukum, Rolpa, Mugu) of Nepal. Every year, hundreds of kilograms of dry *Morchella* are exported to India and overseas. The mushroom *Agaricus bisporus* cultivation in Nepal was first initiated by the Division of plant pathology in 1974. Systemic cultivation of mushroom in Nepal was started by Mr. S.C. Singh, mycologist of Nepal in 1974/75 (Singh, 1998).

The successful technology of *Pleurotus sajor* caju cultivation on chopped rice straw was transferred in the different seasons to various places in the country in 1983. Ultimately, an industry called Himalayan Agro Health Food Pvt. Ltd. was established in 1993 (Thapa, 1995).

The Centre for Agricultural Technology (CAT) has recently introduced straw mushroom (*Volvoriella volvacea*) cultivation in the Terai districts and shiitake in the hill districts and has been instructing farmers how to grow them since 2001. Oyster mushrooms are often grown without any environmental control. *P. sajor* caju is cultivated for the summer crop at Kathmandu (25-30ºC and 80%RH) and in the hills of Nepal while it is cultivated in the Terai regions during the winter season (22-26ºC and 70%RH). *P. ostreatus* is grown during the winter season in Kathmandu and other cool places (5-20ºC and 70%RH). Oyster mushrooms cannot be grown in Terai during the summer (30-40ºC and 70%RH). The mid hills of Nepal are the most appropriate areas for Oyster mushroom production and therefore the mushroom technology has been expanded widely in those villages (Manandhar, 2004).

There are about 5,000 mushroom growers within Kathmandu valley and 6,000 growers in other districts in total, including growers of other mushrooms. Balambu, with a long

history of mushroom growing, has approximately 100 commercial growers and some 100 seasonal growers. They produce 2,000- 3,000kg per day during the summer season (Manandhar, 2004).

The different species of mushroom are grown in different seasons at different altitudes of Nepal. The Table 2.3 shows the data for the different varieties of mushroom grown at different altitudes of Nepal.

Table 2.3 Altitude and time of cultivation of different varieties of mushroom

Region	Species	Season
High altitude (1400 m and above)	*Agaricus bisporus*	September to April
	Pleurotussajor caju	March to October
Medium altitude (800 to 1400 m)	*Agaricus bisporus*	September to February
	Pleurotussajor caju	April to October
	Volvariella volvacae	June to August
Low altitude up to 800 m	*Pleurotussajor* caju	November to March
	Agaricus bisporus	December to February
	Volvariella volvacae	March to October

(Manandhar, 2004)

Nowadays, mushroom cultivation is being introduced as a popular program for income generation in development projects of government of Nepal, NGOs, and INGOs in different parts of the country. Oyster mushroom production is a most appropriate technology for the poor landless farmers and women farmers in Nepal. Mushrooms can be grown in the small space of farmer's own house for small scale production and generate income that aids in the family support. Mushroom cultivation is a most popular activity for development programs targeting income generation among women in Nepal because it is suitable for the women's life style (Manandhar, 2004).

2.11 Mushroom and its products

Mushroom is a versatile vegetable food and can be used in different ways, by mixing with other vegetables or serving separately. Mushroom can be used as a main ingredient and also for flavoring agent in other products; they can be eaten cooked or raw. Different types of products can be prepared from mushroom including mushroom sauce, mushroom flan, and mushroom omelet (Camrass, 1977).

Mushroom has been used as constituents of a great variety of products such as savory risottos, curried meats, meat-pies and puddings and of course mushroom soup. Mushroom can be consumed fresh as curry and other products of mushroom like mushroom omelet, mushroom pickle, mushroom budding, mushroom ketchup etc. (Razia, 1990).

Mushroom can also be utilized for the preparation of weaning foods, biscuits and soup powders. The recipe of different preparations of mushroom dishes like mushroom kidney fry, mushroom curry, mushroom salads, mushroom sandwiches, mushroom stuffed capsicum, stuffed morels, mushroom fritters, meat stuffed mushroom, mushroom hot dogs, mushroom burgers are available (Shrivastava and Kumar, 2002).

Other various products can be made from the different form of mushroom like dehydrated mushroom, mushroom powder, mushroom paste, canned mushroom, frozen mushroom etc. (Arora *et al.*, 2003).

2.11.1 Canned mushroom

Edible mushroom which are not poisonous, are canned in the UK and the US canned mushroom is a delicacy in India and Nepal also. As some of the mushrooms are poisonous, great care is necessary in selecting them for canning as such or in the form of soup. Sometimes they are bleached to a pale color in a solution of sodium sulphite and citric acid. They are then washed thoroughly and blanched for 4 to 5 min in boiling water or in steam, and subsequently dipped in cold water to prevent discoloration. Plain cans and 2% brine is used for packing. Sometimes, to enhance the flavor, about 0.28g of citric acid is added to every 23 liters of brine. To give a friend flavor to the product (when working on a small scale) the mushrooms are cooked in an oven for a few min and a little water, butter and salt are added and stirred prior to filling into cans. Mushroom cultivation is gaining popularity recently. There is scope for canning as well as dehydration of mushroom in developing countries (Girdharilal, 2009).

Beelman *et al.*, (1973) suggested that mushroom soaked for 20 min, stored at 20°C for 18 hr and again soaked for 2 hr prior to canning gives the best result. Mushrooms were blanched in boiling water till temperature of centre reached to 77°C, cooled for 2 min, filled in can and processed at 121°C for 20 min.

2.11.2 Dehydrated mushroom

Drying or dehydration is done to remove free moisture to such a level that the biochemical and microbial activity are checked due to reduced water activity in the product. Freeze drying yields excellent product quality but, the cost of removal of water is ten times higher than the conventional air-drying. Sun drying is appropriate technology for the developing country because of free source of energy and minimum investment in capital cost. Blanching and sulphiting are important treatments given before drying.

The selected non-poisonous mushrooms after the preliminary treatments are sliced into halves and then blanched for three min in boiling water containing 2% salt and 0.1% citric acid. The mushroom is then soaked in a solution containing 1% potassium metabisulphite (KMS), 0.2% citric acid, 6% sugar and 3% salt for about 16 hr. It is then drained and spread on trays and dried at 60±2ºC for 8 hr or up to moisture content of 5-10%. The dried mushroom is then packed in polythene bag and stored dry place at ambient temperature or marketed (Srivastava, 2002).

2.11.3 Irradiated mushroom

Application of gamma radiation retards the deteriorative processes and helps extend their shelf-life. Doses of 1-2 KGy delays cap opening and stalk elongation in button mushroom, extending their marketability and also increases their storage life for 9-10 days at 15ºC (Srivastava, 2002).

Roy *et al.,* (2000) found that gamma irradiation at the level of 0.5 KGy could be extended the shelf life of *Pleurotus sajar* caju up to 90 days at 15^0C compared to 6 days of control.

2.11.4 Frozen mushroom

Kondratowicz and Dajanowska (2000) used liquid CO_2 to freeze (-70^0C) *Pleurotus ostreatus* mushrooms and concluded that mushroom could be stored in refrigerated conditions for more than 90 days. Treating *Agaricus bisporus* before freezing in 3000-5000 ppm KMS, blanching in boiling water for 20 sec and storage at -20^0C for 90 days gave frozen products a good color and appearance. The residual SO_2 of this sample was 52 mg/kg on day 1, which decreased to 42 mg/kg on day 14 and remained on this level during rest of storage.

2.12 Drying or dehydration of fruits and vegetables

Drying is probably the oldest method of food preservation (Heid, 1981). As we know that drying is the most popular method of food processing accepted by our ancestors from the time immortal and is well known to every part of earth. The terms like dehydration, drying and evaporation though seems to be similar have different meanings.

From engineering point of view, drying is the unit operation in which nearly all the free moisture present in the food stuff is removed by evaporation or sublimation as a result of application of heat under controlled condition (Lilly *et al.,* 1976).

Though dehydration and drying is used synonymously, there are some distinctions made by many writers.

a) The process of drying in technical field referred as a natural process in which solar energy is utilized directly in drying the food stuff and usually held in open environment while dehydration is an artificial operation which implies control over the drying condition within the closed micro environment and uses heat energy, other than radiation, supplied through various medium and methods.
b) In several literatures it has been outlined that dehydration, through expensive and needs skilled workers, has many merits over the drying counterpart e.g. drying area and time required is less; suitable to mechanization for industrial scale and the quality of the finished product is more improved (Badger *et al.,*, 1955).

Dehydration or drying of foods is a complex phenomenon involving momentum, heat and mass transfer, physical properties of the food, air and water vapor mixtures, and macro and microstructure of the food. There are various possible drying mechanisms, but those that control the drying of a practical product depend on its structure and the drying parameters, drying conditions, moisture content, dimensions, surface transfer rates, and equilibrium moisture content (Rizvi and Mittal, 199?).

2.12.1 Significance of drying

Vegetables which come seasonally in gluts cannot be kept for a long time without preservation. Vegetable processing has several objectives:

a) To make seasonal glut production available throughout the year.
b) To retain maximum nutrients, texture and flavors as in fresh vegetables.

c) To prevent the spoilage of perishable foods, thereby increasing per capita consumption which is less than adequate in developing countries like Nepal.
d) To increase export.

Many contributors have discussed relative importance of drying of food stuffs (White, 1973).

The main purpose of drying is to concentrate the product by reducing moisture, consequently the water activity (a_w) (Lee, 1975). According to Lee, bacterial growth is checked below a_w of 0.90 and between 0.80, inhibits the growth of molds and yeasts.

The reduction of moisture is accompanied by reduction in weight and frequently in volume of the food, thus, resulting maximum count of food with the smallest possible amount of weight storage space (Trucker, 1969).

2.12.2 Theory of drying

The process of drying must be approached from two points of view: first, the equilibrium relationship and, second, the rate relationships. There is always heat transfer to the material in a variety of ways. The vaporization of water from a surface into a stream of air, capillary movement of moisture etc is some of the way for the movement of moisture (Badger, 1995).

Dehydration or drying of foods is a complex phenomenon involving momentum, heat and mass transfer, physical properties of the food, air and water vapor mixtures, and macro and microstructure of the food. There are various possible drying mechanisms, but those that control the drying of a practical product depend on its structure and the drying parameters, drying conditions, moisture content, dimensions, surface transfer rates, and equilibrium moisture content (EMC). These mechanism falls into three classes viz.

1) Evaporation from a free surface,
2) Flow as a liquid in capillaries and
3) Diffusion as a liquid or vapor.

The first mechanism follows the laws for heat and mass transfer for a moist object. The second mechanism becomes difficult to distinguish from diffusion when one sets the surface tension potential to be proportional to the logarithm of the moisture potential (water activity). The third set of mechanism follows Fick's law of diffusion, which is

analogous of heat transfer when the appropriate driving force is used (Rizvi and Mittal, 199?).

In conventional drying the heating medium, generally air, comes into direct contact with the solid. Various ovens, rotary, fluidized bed, spray dryers are some examples. In conduction drying, the heating medium is separated from the solid by a hot conducting surface. Examples are drum, cone, and through dryers. In radiation dryers, the heat is transmitted as radiant energy. Some dryers also use microwave energy to dry food materials at atmospheric pressure or at vacuum (Rizvi and Mittal, 199?).

2.12.3 Basic principles of air-drying

Krokida *et al.,* (2002) studied the hot air drying and reported that as a conventional drying technology and commonly used for drying grains, fruits, vegetables and nuts. It was based on the flow of dried air through food in the chamber to evaporate moisture in food. A major disadvantage of hot air drying was low energy efficiency and lengthy drying time during the falling rate drying period. This was mainly caused by rapid reduction of surface moisture and consequent material shrinkage, which often results in reduced heat and moisture transfer. Prolonged exposure to elevate drying temperatures may result in substantial degradation in quality attributes such as color, nutrient, and flavor. Severe shrinkage also reduces bulk density and rehydration capacity. Hot-air drying was the most commonly used method for food dehydration, which has the advantage of reducing the costs of packaging, storage, and transport due to the low volume and weight of the final product.

During the drying of a wet solid, it comes into contact with a stream of hot and dry air at a given temperature and humidity, flowing parallel to the drying surface throughout the cycle, the moisture will be removed until an equilibrium moisture content established, simultaneously, from the solid through air while air supplies the necessary sensible and latent heat of evaporation to the moisture and also acts as a carrier gas for the removal of the water vapor formed from the vicinity of the evaporating surface (Lilly *et al.*, 1976).

The free water present in each mole in the solid is perpetually in motion which will be accelerated by increasing the temperature and continues escaping into the surrounding until a state of dynamic equilibrium is reached that depend upon the temperature and water

vapor pressure difference (WVPD) between the wet food stuff and atmosphere (Burton, 1982).

According to Burton, (1982) a continuous supply of dry air stream can affect or change the WVDP either by diluting the water vapor of air bulk or by sweeping away stagnant zone of high humidity or by changing the temperature.

2.12.4 Equilibrium moisture content (EMC)

In general, if a wet solid is brought into contact with hot air at a constant temperature and humidity until equilibrium is reached, in such a case the solid will reach a definite moisture content that will be unchanged by further exposure to the same air. This is known as equilibrium moisture content (EMC) of the material under the specified condition (Lilly *et al.*, 1976).

EMC is defined as the moisture content when vapor pressure of water present in the food material has reached to the equilibrium with its surroundings. It is a thermodynamic entity and has practical significance in both drying and storage of foods. It is affected by both relative humidity and temperature of the surroundings. Water activity is defined as the ratio of vapor pressure of water in the foodstuff to the vapor pressure of pure water at the same temperature. That is:

$$a_w = (P/P_o) = (ERH/100)$$

Where a_w the water activity (dimensionless), P is vapor pressure of water present in food, P_o represents vapor pressure of pure water, T is absolute temperature (K), and ERH is equilibrium relative humidity (%).

Water activity controls microbiological growth, enzymatic activity, and packaging requirement. Information on the sorption isotherms is important in the design of drying processes and microbiological safety (Rizvi and Mittal, 199?). EMC value varies with material and temperature. It can be pointed out that the EMC of solid decreases with an increase in air temperature (Shrestha, 1985).

2.12.5 Drying rates and phase diagram of drying

According to Lilly *et al.* (1976), if the change in moisture content is recorded throughout drying under ideal condition then the data can be presented in the form of curves as shown in the Fig. 2.2 consisting number of stages.

2.9.5.1 Stage A (A') - B

It represents the setting down period during which the solid surface conditions come into equilibrium with the drying air and is often negligible proportion of the overall drying cycle but in some cases, may be significant.

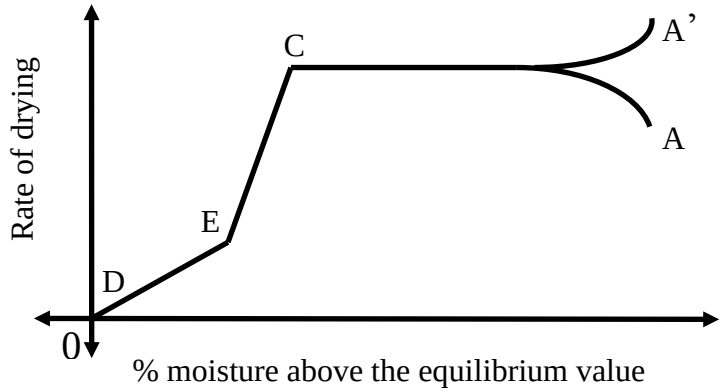

Fig. 2.2 Generalized rate of drying curve for solid material.

2.9.5.2 Stage B- C

It represents the constant rate period. Here surface of solid remains saturated with water by virtue of the fact that movement of water within the solid to the surface takes place at a rate greater than the rate of evaporation from the surface. Drying takes place by the movement of water vapor from the saturated surface through a stagnant air film into the main stream of drying air. The rate of drying is dependent on the rate of heat transfer to the drying surface. The rate of mass transfer balances the rate of heat transfer and so the temperature of drying surface remains constant (Lilly *et al.*, 1976).

2.9.5.3 Stage C- D

It represents the falling rate period. As drying proceeds a point is reached at which the rate of movement of moisture within the material to the surface is reduced to the extent that the surface begins to dry out. At this point 'C', the rate of drying begins to fall and the falling rate period commences. The moisture content of material at point 'C' is known as the critical moisture content (W_C). However, from point 'C' on wards the surface temperature begins to rise and continues to do so as drying proceeds, approaching the dry bulb temperature (Lilly *et al.*, 1976).

Often falling rate period consists of two parts C- E and E- D respectively where drying rate falls further from 'E'. Second falling rate period begins as the surface dry completely (Badger *et al.*, 1995).Usually, this period represents the major portion of the overall drying time. Heat is transferred from the air to dry surface of solid, then to zone of vaporization while water is vaporized within the solid and then to air (Badger *et al.*, 1995

The Fig. 2.3 describes the same phenomena of drying and is called the drying curve which is simply the plot of moisture (db) versus time. Fig. 2.3 represents a typical drying curve for mushroom.

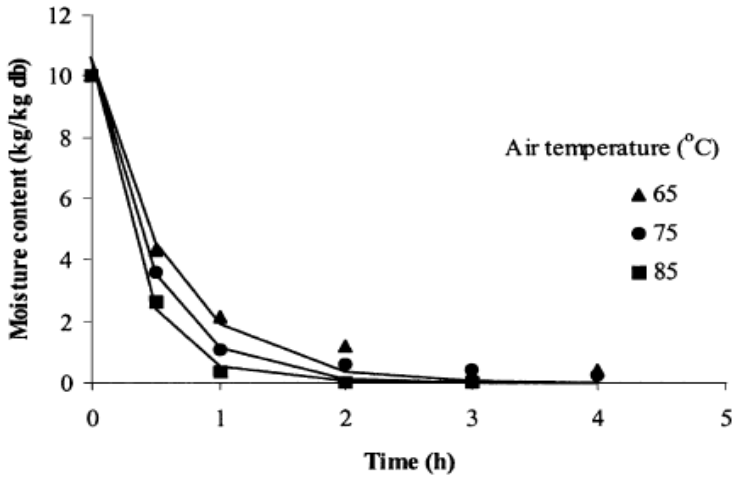

Fig 2.3 Drying curve of mushroom at different temperature

(Krokida *et. al.*, 2003)

2.13 The drying process of food

In the drying process three types of bound water could be seen in food materials.

1. Water molecules which were bound to ionic groups
2. Water molecules which were hydrogen bonded to hydroxyl and amide groups
3. Unbound free water found in interstitial pores in which capillary forces and soluble constituents could cause lowering of vapor pressure (Badger, 1995).

Badger, (1995) studied the drying phenomenon and concluded that the drying rate includes different periods, first the moisture was removed by evaporation from the saturated surface, and next the area of saturated surface gradually decreases, followed by water evaporation in the interior parts of the sample. In the drying curve three periods could be identified as warming up, constant rate and falling rate. The exchange point which drying rate changes from constant rate to falling rate of drying curve was termed critical

moisture content. The warming up period was of little consequence in most cases because of its short duration. Either the constant rate or falling rate period may constitute the major portion of the drying time. During the constant rate drying period, the rate of moisture removal from the product was limited only by the rate of evaporation on water surfaces on or within the product. In this constant-rate period, the water was being evaporated from what is effectively a free water surface. The illustrative figure for the phenomenon of drying and moisture removal is shown in Fig 2.4.

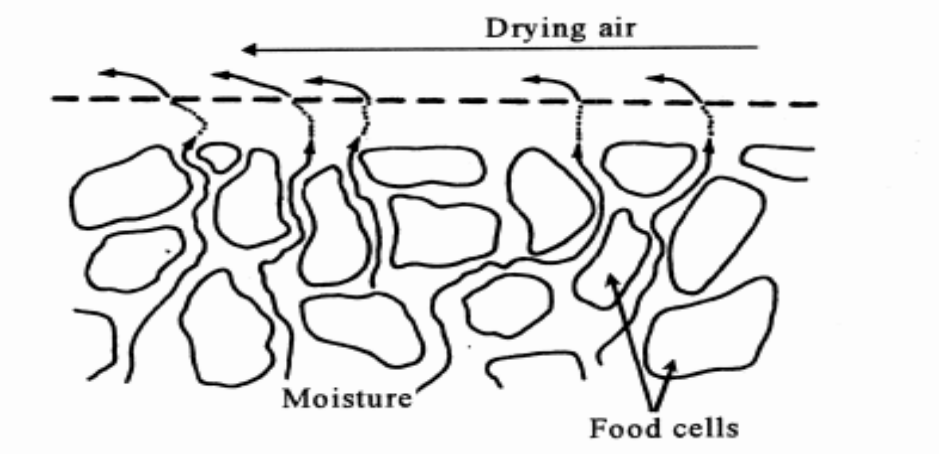

Fig.2.4 Process of food dehydration

(Rehmann, 2002)

Brennan, (2006) reported that the rate of removal of water could then be related to the rate of heat transfer, if there was no change in the temperature of the material and therefore all heat energy transferred to it may result in evaporation of water. Some food materials do not show constant rate drying period.

A constant rate drying period was not detected in drying curves of chilli (Akpinar, 2003), apricot (Togrul, 2003), carrot, corn, tomato, mushroom, garlic, onion, spinach, green pepper, red pepper, pumpkin, yellow pepper, green pea, leek and celery (Krokida *et al.*, 2003).

2.14 Effect of drying on fruit and vegetable quality

The quality of dried foods depends not only on the drying process but the quality of raw materials, pretreatment process (i.e., blanching, chemical treatment, freezing) and storage condition of the final product. Quality changes of food materials were common phenomena during drying. Quality parameters were very important and application of drying method

should not deteriorate the quality parameters of the food. There were some quality changes during drying of food material. Crapiste, (2000) has mentioned about quality changes during drying.

Quality changes were divided into physical & structural, chemical & organoleptic and nutritional. Physical & structural include shrinkage cell, structure damage and volatile retention and their quality effects were volume, texture, rehydration ability, solute loss aroma loss.

Chemical and organoleptic quality includes browning reactions, lipid oxidation, pigment degradation and enzyme inactivation. Its quality effects were darkening, off-flavor development rancidity, off-flavor development, color loss, flavor and pungency loss.

Nutritional include microbial death, protein denaturation and vitamin degradation and its quality effects were microbial survival, loss of biological value and loss of nutritive value (Crapiste, 2000).

2.15 Technology of mushroom drying

2.15.1 Pre treatments prior to mushroom drying

2.15.1.1 Blanching of mushroom

Blanching is a critical step in processing fruit and vegetables due to the changes it causes such as enzyme inactivation, air removal, and leaching of nutrients. This process has an important effect on texture and moisture transfer (Bhalla, 1986).

Bhalla (1986) stated that boiling water or steam may be used in the blanching of mushroom, and blanching times are adjusted accordingly to bring the center temperature of mushroom to about 77 ºC.

Considine (1982) explained that mushroom is blanched in either a hot water density blancher or a screw type blancher. In a density type blancher the raw mushroom will initially float but when heated, due to density change, will sink to a discharge unit. The screw type blancher is controlled by the speed of a mechanical screw. In either type of blancher the center temperature of the blanched mushroom must be minimal of 77ºC.

Girdhari lal *et al.,* (1986) mentioned that mushroom are washed thoroughly and blanched for 4-5 min in boiling water or steam, and subsequently dipped in cold water for 2 to 3 min for blanching.

2.15.1.2 Sulfitation of mushroom

The color and shelf-life of the dried products could be improved by using chemical preservatives. The browning reaction continues after drying and dried vegetables will continue to darken during storage unless they have been treated with sulfur dioxide (SO_2). The presence of SO_2 in the dried vegetables will also inhibit the microbial spoilage and will help to deter insect both during drying and later in storage (Bhalla, 1986).

According to Poter (1987) sulfur dioxide may function in several ways. Sulfur dioxide is an enzyme poison against common oxidizing enzymes. It also has an antioxidising property that is an oxygen acceptor (as is ascorbic acid). Further, SO_2 minimizes non-enzymatic reaction Millard type browning by reacting with aldehyde groups of sugar, so that they would no longer be free to combine with amino acids. Sulfuring of fruits and vegetables also causes a great reduction in number of microorganisms and serves to inhibit growth in dried product.

Komanowsky (1970) have investigated air drying of mushroom. Excessive blanching has found to produce very dark products, presumably owing to the loss of soluble compounds which inhibit non-enzymatic browning. An improvement was achieved by mild sulfite treatment.

2.15.2 Mushroom drying or dehydration

Zhuk and Tsapalova (1973) recommended a temperature of 60°C for mushroom drying. Jorege and Chanes (1992) found a temperature of 60°C adequate for air-drying of mushrooms. Singh (1996) recommended a temperature of 60°C for drying. He suggested 7 hrs drying time to achieve 5 % moisture level from 92%.

Pruthi *et al.,* (1978) found that paddy straw mushroom dried best at 70°C, 65°C and 60°C to 55°C for a period of 2 hr, 2 hr and 4 hr respectively. Dehydration ratio and rehydration ratio of the dried samples varied from 10.0 to 11.1 and 3.2 to 7.5 respectively.

Lal and Sharma (1995) recommended a finishing temperature of not more than 65.5°C. Pruthi *et al.,* (1978) demonstrated dehydration of paddy straw mushroom in multistage dryer at 70°C, 65°C and 60°C. Drying in multistage dryer gave better results with respect to color.

Singh *et al.,* (2007) performed tray drying of button mushroom. Pieces of 0.5, 0.7 and 0.9 cm thick button mushrooms were dehydrated in tray dryer at 40°C, 45°C, 50°C and 55°C and their drying characteristics such as rate of diffusion and rehydration ratio were studied. The qualities of dehydrated pieces were evaluated on the basis of color, veil opening and amino acid content. The mushroom dehydrated at 50^0C showed better quality.

During initial phase of drying, short time interval is to be taken and it is to be increased till the last phase of drying. The drying should be performed till the samples attained a constant weight for the last 3 readings (Srivastava, 2009).

Giri and Prasad (2007) studied the effect of drying in at 50, 60 and 70°C in crossflow type dryer at air velocity of 1.5 m/s on mushroom quality. They found better results with respect to color, rehydration ratio and overall acceptance.

Komanowsky (1970) instead of an initial drying stage at high temperature of 75ºC and finishing off at about 60ºC found that by first treating the mushroom pieces for 5-10 min in solution of 400 ppm Cl_2 and 300 ppm SO_2 then drying at 45ºC for 4 hr followed by a second stage drying for one hr at 75ºC produced a dried pieces of attractive light color. He further mentioned that an end product with good flavor and storage stability and a better color and shape was obtained by dehydrating unbalanced mushroom. Chemical treatment viz. citric acid, table salt, ascorbic acid, EDTA or sodium acid pyrophosphate had little effects on the color of the dried mushroom.

2.16 Rehydration of mushroom

Rehydration ratio (RR) is a measure of rehydration characteristics of dried mushroom slices which is generally determined by immersing dried samples in distilled water (warm or cold) for a sufficient time.

Van Arsdle (1973) found the drying ratio of freeze dried mushroom was about 3.3: 1, while the rehydration ratio of air dried mushroom was found to be 2.4: 1. Lidhoo and Agrawal (2008) suggested that hot-air drying temperature of 65ºC was found to produce a product of desired quality that was also acceptable to consumers which had a rehydration ratio of 2.9.

Oyster mushroom shows a rehydration ratio of 2.3-3.4:1 under various conditions of pressure and temperature. Rehydration properties are improved by drying at higher

temperature and lower pressure as indicated by higher value of rehydration ratio (Durance and Wang, 2002).

Mudahar and Bains (1982) reported a rehydration ratio of 2.6 for blanched *Agaricus bisporus* mushroom dried in two stage using air temperature of 45±2ºC followed by 60±2ºC and the rehydration ratio was decreased linearly with increasing temperature.

Part III

Materials and methods

3.1 Raw materials

Good quality mushroom of *P. sajor* caju variety were purchased from Simadia VDC. of Sunsari district. The fresh samples were taken in batches because of perishability. However the samples were collected at a particular stage of maturity i.e. when the radius of the disc of mushroom reached minimum of 1-1.5 inch.

3.2 Washing and cutting

The collected fresh mushrooms were sorted and washed. The sorted mushroom is then sliced into two to four halves as the part of preliminary preparations. The average size of mushroom was made about 3.0 cm×3.0 cm ×5.0 cm with SS knife (Walde *et. al,* 2005).

3.3 Optimization of blanching time

The blanching time was optimized according to NARC, (200?). 10 g of sliced mushroom was blanched in plain water at 85ºC for 0, 30, 60, 90, 120, 150, 180, 210 seconds followed by cooling in cold water. They were then grinded in a mortar and pestle with 50 ml distilled water, and then filtered through muslin cloth and the filtrate was made up to 100 ml with distilled water.

The adequacy of blanching was checked by peroxidase test. Five ml of the sample solution was taken in 20 ml test tubes. In these solutions 10 ml distilled water, 1 ml guaiacol in 95% ethyl alcohol (1%) and 1 ml fresh H_2O_2(0.5%) were added and mixed thoroughly. The test- tubes were left for 5-10min and the color of the sample was compared with the control.

3.4 Sulfitation

The mushroom samples were sulfited by dipping into 0.3% KMS solution for 10 min (NARC, 200?).

3.5 Drying

The samples viz. fresh, blanched, sulfited, blanched and sulfited were weighed and were dehydrated at 60ºC in a cabinet dryer (Research Equipment and Instrument Company-15,

model no. Rid/5, SI.NC. -4/440). The samples were weighed at an interval of 0.5 hr until three concurrent readings. The effects of different pretreatment on the drying characteristics were studied. The dehydrated samples were analyzed for vitamin C, non-enzymatic browning (NEB), rehydration ratio (RR), rehydration coefficient (RC), percent water in the rehydrated mushroom (WRM) and sensory parameters. The overall drying process is shown in Fig. 3.1.

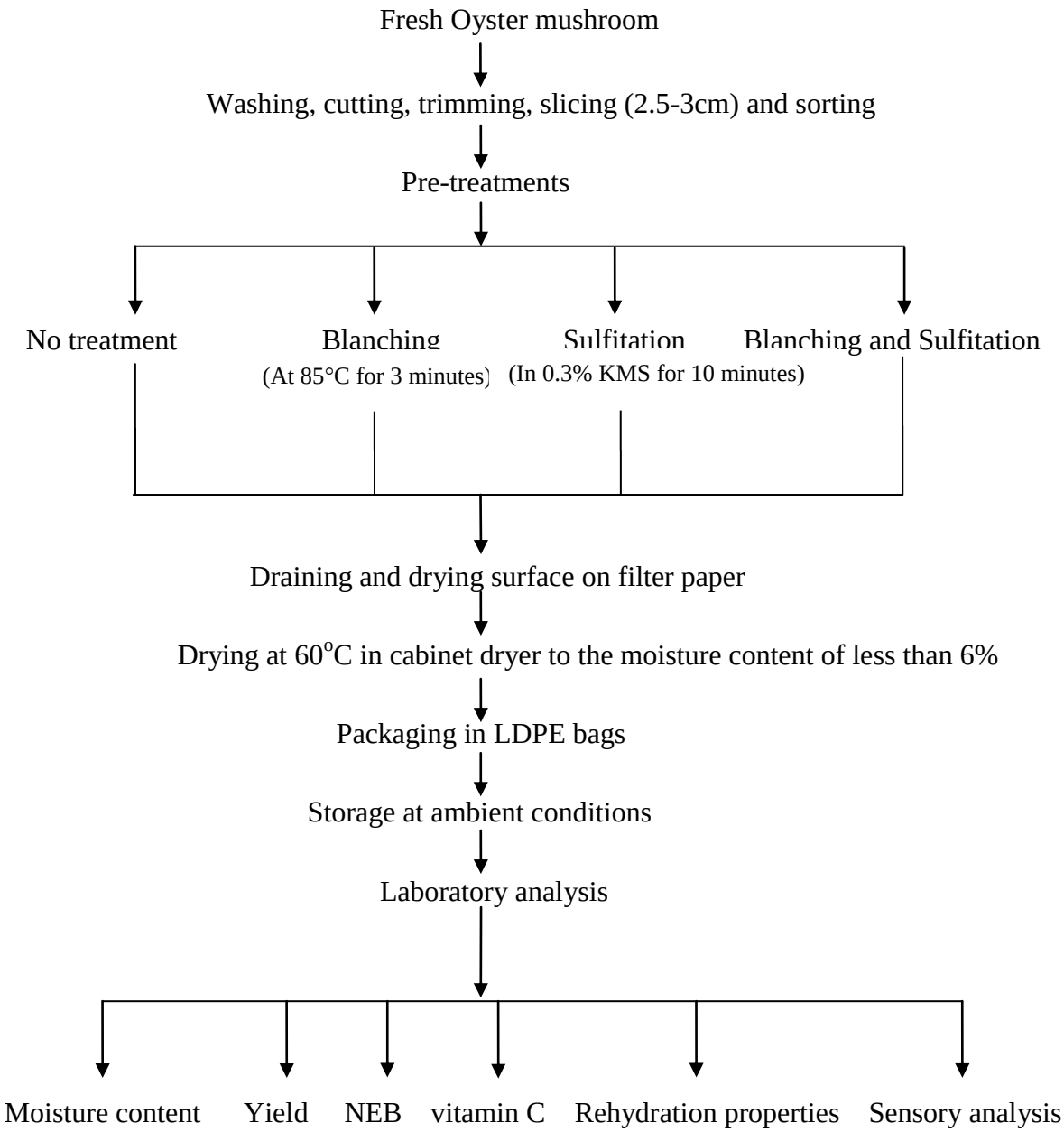

Fig. 3.1 Flow diagram of Oyster mushroom dehydration

3.6 Drying curve fitting

The different drying curves were plotted between moisture content (db) and time to study the drying characteristics of Oyster mushroom from the data recorded during the dehydration (Brennan *et al.,* 1976).

For the determination of the drying rate curves, the drying rate is plotted against moisture content (db) and time respectively. These curves can be used to describe the drying characteristics of mushroom. The drying curves were fitted for linear, polynomial and exponential models and their R^2 values i.e. the coefficient of determination are compared by Microsoft excel 2007.

3.7 Packaging

The dried samples were packed in LDPE (low density polyethylene) bags and then sealed air tight and stored at ambient temperature. The finished product was used further for analysis.

3.8 Sensory analysis

The different samples of dried mushrooms were evaluated for sensory parameters viz., color, odor, taste, appearance and overall acceptance with the help of 9 point hedonic scale following the standard procedure given by the Bureau of Indian standards (IS: 6273) by 10 semi-trained panelists of CCT, Dharan.

3.9 Analytical procedure

3.9.1 Determination of moisture content

The moisture determination of the mushroom (both fresh and dried) was carried out by hot-air oven method (Ranganna, 1986).

3.9.2 Determination of vitamin C (ascorbic acid)

The ascorbic acid content of mushroom was determined by 2, 6-Dichlorophenol-indophenol visual titration method (Ranganna, 1986).

3.9.3 Determination of non-enzymatic browning (NEB)

The mushroom color, an important quality determinant was measured in terms of non-enzymatic browning. The increase in absorbance of the sample extract at 440 nm

wavelength was taken as a measure of the non-enzymatic browning. The test was carried out as per the procedure outlined by Ranganna (1986). The extract was prepared by soaking 5 g of dried sample in 100 ml of 60% ethyl alcohol for 12 hr and filtered with whatmann no. 1 filter paper. The optical density was recorded at 420 nm using a spectrophotometer.

3.9.4 Determination of rehydration ratio, rehydration coefficient and percent water in rehydrated mushroom

The rehydration ratio of dried mushroom pieces was determined by soaking 2 g of each sample in seven times its weight of distilled water at room temperature in covered glass beakers for overnight (Pruthi *et al.* 1978). The calculations were done using formula given in Ranganna (1986).

3.10 Data analysis

All experiments were performed in triplicate and the data analysis was done statistically by GENSTAT discovery edition 3 for one-way and two-way ANOVA. The drying data were fitted using the MS office 2007 for coefficient of determination of various models.

Part IV

Results and Discussions

This chapter deals with the results of the experiments carried out to explore the drying characteristics and rehydration properties of Oyster mushroom under different pretreatments. Oyster mushroom being an organic food produce, its drying behavior is complex and the nature of drying is affected by various factors including the physical nature of raw material, yield after drying, blanching tests and other treatments.

Following the successive operation of slicing and washing, mushroom was pre-treated and then dried. Since the moisture change was of primary importance, moisture content of mushroom prior to drying and after the completion of drying was determined. Also the length of drying and Yield of dehydrated mushroom was analyzed after dehydration. The vitamin C, browning, rehydration characteristics and sensory analysis were also carried out.

Since the primary objective of this study is to determine the drying characteristics of different mushroom, the detail of moisture change during drying have been illustrated in four different drying curves and compared the drying characteristics.

As the dried mushroom is used in culinary purpose and other many purpose along with in powdered form to manufacture infant diet, soup base and mushroom paste; different rehydration tests were also performed for the all four groups of dried mushroom and the properties were compared to opt for the best method under study.

4.1 Blanching time optimization

An optimum blanching time for Oyster mushroom slices (3.0 cm×3.0 cm ×5.0 cm) in water at 85ºC was determined by peroxidase test (Walde *et al,* 2006). The blanching time of Oyster mushroom was found to be 3 min at 85ºC. This result is in accordance with the report of NARC (200?) and results are shown in Table 4.1.

Luh and Woodroof (1975) suggested the blanching time of 2-5 min at the boiling temperature i.e. 98± 2°C of water for button mushroom. Lidhoo and Agrawal (2008) reported the blanching time of 3 min at 84-96ºC for mushroom for oyster mushroom. The work carried out by Hoogzand and Doesburg (1961) and Azizi and Ranganna (1993)

suggested the time of 3 min at the boiling temperature of water to be sufficient for blanching of vegetable products.

Table 4.1 Peroxidase test for Oyster mushroom blanching at 85ºC

	Blanching time (seconds)								
Sample no.	0	30	60	90	120	150	180	210	240
1	+	+	+	+	+	+	-	-	-
2	+	+	+	+	+	+	-	-	-
3	+	+	+	+	+	+	-	-	-

('+' indicates the positive peroxidase test; '-' denotes the negative peroxidase test)

4.2 Moisture content of mushroom before and after drying

The moisture content of raw Oyster mushroom was determined by hot- air oven method. The moisture content of raw oyster mushroom was found to be 91.46% as in average of three batches which is within the range (86.5% to 92%) reported by Pruthi *et al.*, (1978). The variation in moisture content of mushroom may be due to difference in variety, growing season, climatic conditions, harvesting frequency (Arumuganthan *et al.*, 2008).

It was found that the moisture content of treated samples after drying was lesser than that of untreated sample. Among the treated samples, the blanched sample retained the least moisture content followed by 'blanched and sulfited' and sulfited (Fig.4.1). The moisture content of the dried product is shown in Table 4.2.

Table 4.2 moisture content of dried Oyster mushroom pieces

Samples	moisture content (% wb)
Fresh	5.025^{a} (0.304)
Blanched	4.575^{a} (0.063)
Sulfited	4.68^{a} (0.282)
Blanched and sulfited	4.58^{a} (0.127)

(Values are the mean of triplicates and values in the parentheses are the standard deviation)

(Values with same superscript are not significantly different)

The statistical analysis showed no significant effect of pretreatments on moisture content of dehydrated mushrooms at 5% level of significance. The ANOVA for effect of pretreatment on moisture content is given in Appendix B (Table B.12).

The moisture content of dried sample is in accordance with Giri and Prasad, (2008). They suggested the safe moisture content of 6% for dehydrated mushroom. The present result is also in accordance with Luh and Woodroof, (1975), Srivastava *et al.,* (2009); who reported the safe moisture content of 6% and 5% respectively. Lidhoo and Agrawal, (2008) recommends the moisture content 5% or less for safe storage of mushroom.

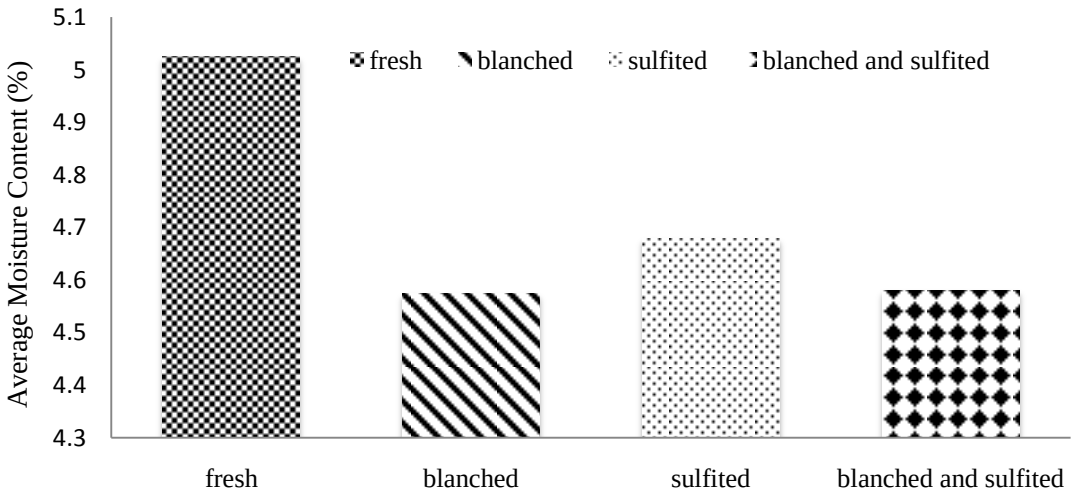

Fig. 4.1 moisture content of dried Oyster mushroom pieces

4.3 Drying time of Oyster mushroom pieces

The drying time required to attain the equilibrium moisture content for all final product was found to be in the range of 5 to 6.5hrs. The drying time for different samples is shown in Table 4.3.

Table 4.3 Drying time for Oyster mushroom pieces

Samples	Drying time (hrs)
Fresh	6.5^{a} (0.5)
Blanched	5.33^{bc} (0.288)
Sulfited	5.5^{c} (0.0)
Blanched and sulfited	5^{ac} (0.0)

(Values are the mean of triplicates and values in the parentheses are the standard deviation)

(Values with same superscript are not significantly different)

The drying time for the fresh Oyster mushroom was found to be 6.5 hrs which is the maximum of all the other treated samples. Among the treated samples, the blanched

sample and sulfited sample had the drying time of 5.33 and 5.5 hrs respectively while the blanched and sulfited sample showed the least drying time of 5 hrs. Arumuganthan *et al.,* (2008) found the drying time of 5 to 7 hrs for mushroom without any treatments. This is in consistent with present work for untreated sample. Lidhoo and Agrawal (2008), Giri and Prasad (2007), Srivastava *et al.,* (2009) and Krokida *et al.,* (2003) suggested the drying period of 5.5, 4.5, 5.5, and 4.5 hrs respectively for mushroom of different varieties.

The relatively longer drying period of Oyster mushroom in present work may be due to the large pieces of mushroom, low air velocity, uneven humidity.

4.4 Yield of the dried product

The yield of Oyster mushroom was found to be in the range of 82.55 to 84.02 g/kg fresh weight. The maximum yield was found in case of blanched and sulfited sample followed by blanched, sulfited and fresh samples. According to Khanal (1992), the Yield of dried tomato is in the range of 54.72 to 70.42g/kg fresh weight. Generally, the lesser the moisture content the higher is the yield of the dried product.

The statistical analysis showed significant effect of pretreatments on yield of dehydrated mushroom at 5% level of significance. The ANOVA for effect of pretreatment on yield of dehydrated mushroom is given in Appendix B (Table B.13). The yield of final dried product of the entire four groups is tabulated in Table 4.4.

Table 4.4 Yield of the dried Oyster mushroom

Samples	Average yield (g/kg fresh weight)
Fresh	82.55^{b} (0.495)
Blanched	84.02^{a} (0.175)
Sulfited	83.21^{c} (0.224)
Blanched and sulfited	83.94^{a} (0.185)

(Values are the mean of triplicates and values in the parentheses are the standard deviation)

(Values with same superscript are not significantly different)

4.5 Drying curve, Drying rate curve and nature of Oyster mushroom dehydration

Four different drying curves were plotted for the four different samples of Oyster mushroom. The drying curve was plotted for moisture content (db) versus time while the rate curve was plotted for drying rate versus moisture content (db).

The drying curves for drying of fresh, blanched, sulfited, blanched and sulfited samples at 60°C is presented in Fig. 4.2. In the figure, it was indicated that blanched sample loose moisture more rapidly than the others. The study revealed that the non-treated sample took the longest time of drying of 360 min while the other remaining samples took 300 min of drying to reach a safe level of moisture content i.e. less than 6%.

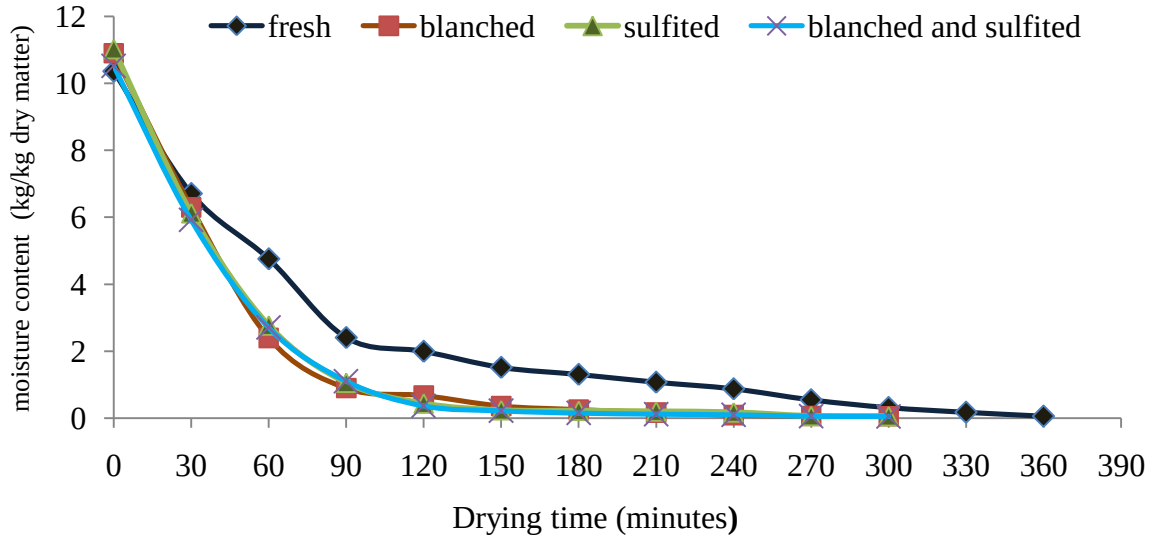

Fig.4.2 Drying curve for mushroom dehydration

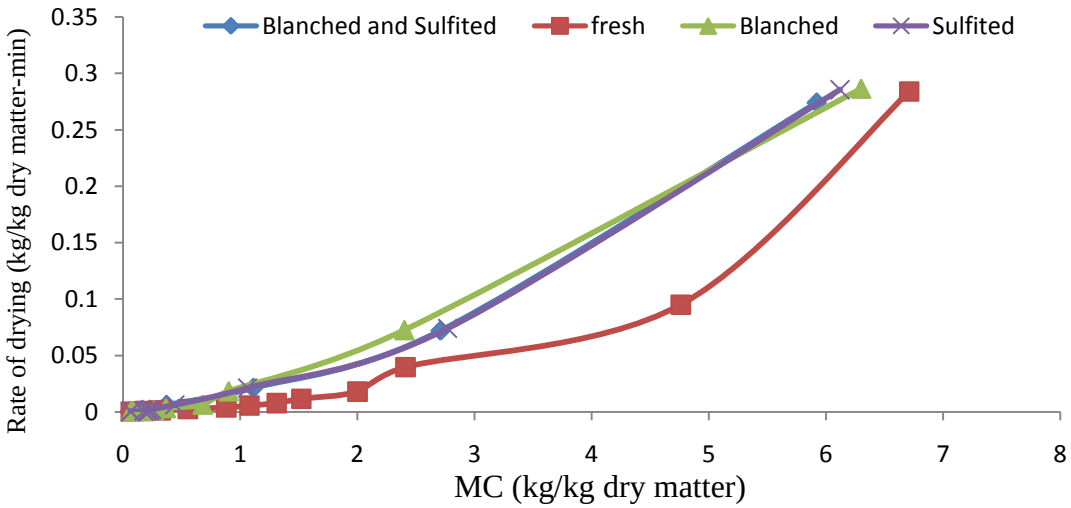

Fig 4.3 Rate of drying versus moisture content (kg/kg dry matter)

Drying rate curve of Oyster mushroom dehydration is shown in the Fig. 4.3. From the graph it can be revealed that the drying rate is highest in case of blanched and sulfited sample followed by sulfited and blanched while the non-treated sample has the least drying rate. From the graph we can also see that there is no stationary rate period in the drying rate

curve. This finding is in consistent with the work of Akpinar, 2003, Togrul, 2003, Krokida *et al.,* 2003 and Giri and Prasad, 2007. From the graph (Fig 4.3), it can also be concluded that the drying temperature is sufficient to draw the moisture efficiently from the surface of mushroom which confirms that this temperature is enough to provide the minimum activation energy for the water molecule to be evaporated and diffused from the surface of oyster mushroom. The absence of the stationary rate period may be attributed to the fact that mushroom was laid on the tray in a thin layer and temperature and air velocity is sufficient to drag the moisture away (Giri and Prasad, 2007). The drying temperature of 60ºC is sufficient to bring the energy required to detach the moisture away from the surface of mushroom (Arumuganathan *et al.,* 2008).

Table 4.5 R^2 values for the modeling of drying curve of mushroom dehydration

	Fresh	Blanched	Sulfited	Blanched and Sulfited
Linear	0.7123	0.5807	0.5839	0.5912
Polynomial	0.9287	0.8986	0.9075	0.9153
Exponential	0.9543	0.9653	0.9318	0.9358

(Values are the mean of triplicates and values in the parentheses are the standard deviation)

(Values with same superscript are not significantly different)

The data for different pretreatments for mushroom drying are fitted for linear, polynomial and exponential model in Microsoft Excel 2007 program. The goodness of fit was determined using coefficient of determination (R^2). The higher R^2 value indicates the good fit for a particular model (Srivastava *et al.,* 2009). The R^2 values for above models are presented in Table 4.5. The exponential model best described the drying curve of Oyster mushroom dehydration and gave better fit for the prediction of moisture content at any drying time at 60^0C. The R^2 value was maximum for the exponential model which is in accordance with Srivastava *et al.,* (2007). Arumugunathan *et al.,* 2008 found the R^2 value of 0.958 to 0.9795 during milky mushroom dehydration.

4.6 Rehydration tests of dried Oyster mushroom

4.6.1 Rehydration ratio (RR)

The rehydration ratio is the ratio of weight of rehydrated sample to weight of dried sample. RR indicates the severity of drying and quality of dehydrated products. Generally, product with high RR is preferred.

The rehydration behavior was analyzed in terms of the ability of the dried mushroom pieces to regain their original product characteristics. The rehydration ratio was found to vary between 2.65 and 3.126 for different pre-drying treatments used for drying. The values of the RR dried at different pretreatments are showed in Table 4.6. The average rehydration ratio for blanched samples and blanched and sulfited sample were found to be 2.65 and 3.126 respectively. The obtained values are higher than reported by Mudahar and Bains (1982), who reported the average RR of 2.32 in case of Button mushroom.

The rehydration ratio was found to be maximum for blanched and sulfited samples followed by sulfited, blanched and fresh samples. The statistical analysis showed significant effect of pretreatments on the RR of rehydrated mushroom pieces at 5% level of significance. The ANOVA for effect of pretreatment on RR is given in Appendix B (Table B.6). The low RR in case of blanched sample may be due to rupturing of cells and tissue during blanching leading to decreased water absorbing capacity. In contrast to our result Singh *et al.,* (2008) found no or very little effect of pre-drying treatments on the rehydration of button mushrooms.

Table 4.6 Rehydration ratio of mushroom treated differently

Pre- treatments	Rehydration ratio
Fresh	2.94^{b} (0.065)
Blanched	2.65^{c} (0.051)
Sulfited	2.99^{ab} (0.114)
Blanched and sulfited	3.12^{a} (0.050)

(Values are the mean of triplicates and values in the parentheses are the standard deviation)

(Values with same superscript are not significantly different)

4.6.2 Rehydration coefficient (RC)

The rehydration coefficient of the rehydrated mushroom is found in the range of 0.332 to 0.419 which is tabulated in Table 4.7. The maximum RC is found in case of blanched and sulfited sample followed by sulfited, fresh and blanched samples.

The statistical analysis showed no significant effect of pretreatments on RC of rehydrated mushrooms at 5% level of significance. The ANOVA for effect of pretreatment on RC is given in Appendix B (Table B.7). The report in this study is in accordance with

the findings of Khanal (1992), who reported that, the RC is affected by pretreatment operations for the dehydration of tomato.

Table 4.7 Rehydration coefficient of mushroom treated differently.

Pre-treatments	Rehydration coefficient
Fresh	0.359^{bc} (0.025)
Blanched	0.343^{b} (0.123)
Sulfited	0.388^{ac} (0.031)
Blanched and sulfited	0.398^{a} (0.018)

(Values are the mean of triplicates and values in the parentheses are the standard deviation)

(Values with same superscript are not significantly different)

4.6.3 Percent water in rehydrated mushroom (PWRM)

The percent water in the rehydrated mushroom is the indicative of water absorption capacity of dehydrated mushroom. Generally, the more is the RR more is the water in the rehydrated mushroom.

The result revealed that the blanched and sulfited sample regained the maximum percent of water (75.20%) followed by fresh, sulfited and blanched samples. The results of percent water in the rehydrated material i.e. Oyster mushroom treated differently is tabulated in Table 4.8.

Table 4.8 Percent water in the rehydrated sample

Pre- treatments	Water in rehydrated sample (%)
Fresh	74.14^{ab} (3.23)
Blanched	70.51^{b} (1.39)
Sulfited	74.013^{ab} (1.33)
Blanched and sulfited	75.2^{a} (2.78)

(Values are the mean of triplicates and values in the parentheses are the standard deviation)

(Values with same superscript are not significantly different)

The water absorption capacity of mushroom seems to be increased due to pre-treatments. The rupturing of cells and vacuoles during treatments may be the causative factor for different results of percent water in the rehydrated sample.

The statistical analysis showed no significant effect of pretreatment on PWRM at 5% level of significance. The ANOVA for effect of pretreatment on RC is given in Appendix B (Table B.8).

4.7 Vitamin C (ascorbic acid) content of the dried mushroom

Ascorbic acid content of dried material is the indicative of nutritive quality and severity of drying of any food material. Generally, ascorbic acid is destroyed at higher drying temperatures (more than 60^{o}C) and longer dehydration periods.

Table 4.9 Vitamin C content in the rehydrated sample

Pre-treatments	Vitamin C (mg/100g dry matter)
Fresh	13.55^{b} (0.78)
Blanched	19.47^{a} (2.42)
Sulfited	24.54^{c} (1.45)
Blanched and sulfited	18.61^{a} (1.68)

(Values are the mean of triplicates and values in the parentheses are the standard deviation)

(Values with same superscript are not significantly different)

The result showed that sulfited sample retained the maximum of ascorbic acid followed by blanched, blanched and sulfited and fresh samples. It is due to the fact that the sulfitation treatment prevented the ascorbic acid from oxidation. The lower reading of vitamin C in case of fresh sample is due to the longer dehydration period which is equally attributed to blanched sample too. The higher retention is due to the application of sulphiting treatment and lower due to no treatments. The vitamin C content of dried mushroom after various treatments is reported in Table 4.9. The vitamin C content of fresh sample was found to be 26.56 mg per 100 g fresh sample.

The statistical analysis showed significant effect of pretreatments on vitamin C at 5% level of significance. The ANOVA for effect of pretreatment on vitamin C is given in Appendix B (Table B.9).

The result found in present work is similar to that of FAO (2006) which reported the vitamin C content 26-27 mg per 100 g dried mushroom. According to Shrivastava and Kumar (2003) the vitamin C loss can amount to 10- 60 % of original in fruits and vegetables.

4.8 Non-enzymatic browning of the mushroom

Non- enzymatic browning is a set of browning reactions which involves the complex reactions of simple sugars with amino acids, peptides and proteins leading to the formation of brown nitrogenous polymers and co-polymers called melanoidins.

The value of OD ranged from minimum of 0.187 to maximum of 0.311. The maximum value obtained in case of Fresh sample is 0.311 followed by blanched, blanched and sulfited and sulfited sample. The browning index i.e. optical density (OD) values of mushroom dried under different pre-treatments are given in Table 4.10.

The lower OD in the samples other than fresh is due to the pre-treatments viz. sulfitation and blanching. The fresh sample had suffered from enzymatic and non-enzymatic browning due to lack of any pre-treatments and drying temperature. Thus, from the view point of browning which is the indicative of color of the dried mushroom, the best mushroom dehydration process would be to dry the mushroom pieces after sulfitation.

Table 4.10 Non-enzymatic browning in the rehydrated sample

Pre-treatments	OD
Fresh	0.311^{a} (0.070)
Blanched	0.216^{b} (0.018)
Sulfited	0.187^{b} (0.012)
Blanched and sulfited	0.189^{b} (0.010)

(Values are the mean of triplicates and values in the parentheses are the standard deviation)

(Values with same superscript are not significantly different)

The statistical analysis showed no significant effect of pretreatments on NEB and pretreatments of rehydrated mushrooms at 5% level of significance. The ANOVA for effect of pretreatment on vitamin C is given in Appendix B (Table B.10).

Sethi *et al.,* (199?) advocated the range of 0.083 to 1.656 in case of *Agaricus bisporus* which supports the result of present work. Suguna *et al.,* (1995) reported the range of 0.1 to 0.35 in case of Oyster mushroom while using air temperature of 60-75 °C. Lidhoo and Agrawal, (2008) suggested the OD of 0.162 as average for *Agaricus bisporus.*

4.9 Sensory evaluation of the rehydrated mushroom

The raw data of sensory evaluation and the ANOVA are tabulated in Appendix A (Table A.1). The summary of the statistical test for difference between the pre-treatments and mean grading of sensory attributes of samples in terms of superiority is shown in Table 4.11 and 4.12 respectively.

The statistical analysis was performed for sensory attributes using the ANOVA in order to establish the effect of pre-treatments and is shown in Appendix B (Table B.1-B.5). The analysis showed significant effect of pretreatments on color, taste, appearance and overall acceptability except flavor at 5% level of significance.

It was observed that the mean score for various sensory attributes of mushroom dried under different pretreatments varied from 4.1 to 7.4 out of the highest possible mean score of 9 indicating that the pretreatments created variability in the dried product. The mean sensory score in this finding is in accordance with that of Lidhoo and Agrawal, 2008 who reported the mean score of 4.3 to 7.8 in case of mushroom dehydration.

Table 4.11 Summary for the statistical test for difference between the treatments

Treatments	Color	Flavor	Taste	Appearance	Overall
A	7.2^{ab}	6.2^{a}	6.8^{a}	7^{a}	6.7^{a}
B	5^{c}	4.1^{b}	4.2^{b}	5.1^{b}	5.1^{c}
C	6.4^{b}	5.6^{a}	4.9^{b}	5.8^{b}	5.8^{b}
D	7.4^{a}	6.5^{a}	6.6^{a}	7^{a}	6.8^{a}
LSD	0.924	1.394	1.143	0.566	0.647

(Values are the mean of triplicates and values with same superscript are not significantly different)

Table 4.12 Overall grading of attributes in terms of superiority

Quality attributes	Superiority
Color	[D/A] > [A/C] > [B]
Flavor	[D/A/C] > [B]
Taste	[A/D] > [C] > [B]
Appearance	[A/D] > [B/C]
Overall	[D/A] > [C] > [B]

The codes A, B, C, D denotes non-treated, blanched, sulfited and blanched and sulfited mushroom after dehydration respectively. The Table 4.11 explains the difference test

between various pretreatments. From the table it can be revealed that all the sensory attributes are significantly different at 5% level of significance according to difference test. However, to determine the best product; superiority Table 4.12 is created, which suggested that sample D i.e. blanched and sulfited consistently ranked best and is recommended.

The impact on various quality attributes of the dried mushroom can be easily be estimated from the Fig. 4.4. From the Fig. 4.4, it can be easily estimated that blanched and sulfited sample is the best among all the other samples with respect to the above mentioned quality attributes. However, the quality attributes of other mushroom slices was only marginally poor from the best rated sample.

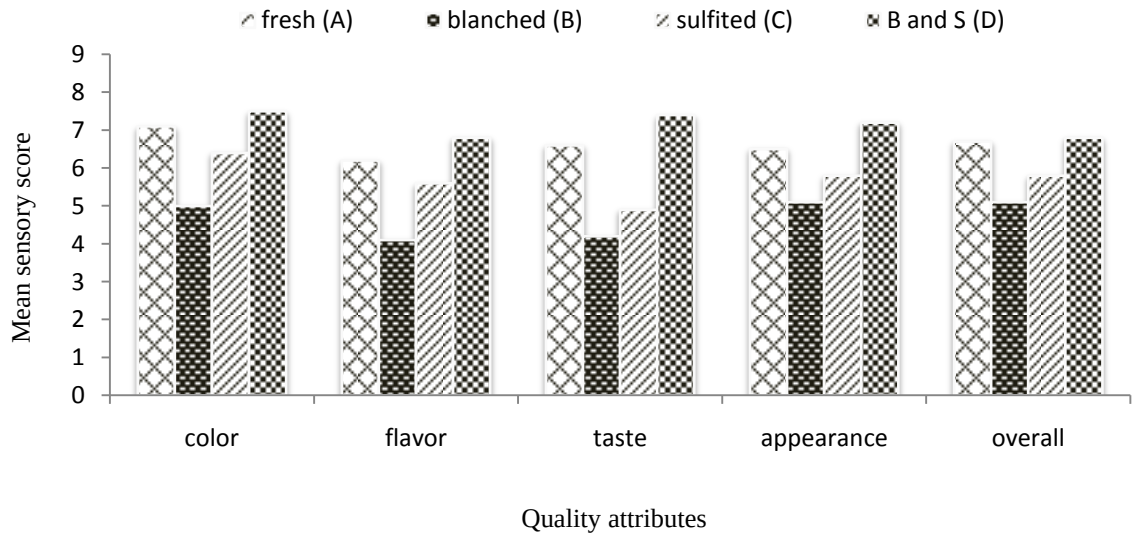

Fig. 4.4 Effect of pretreatments on the mean sensory score of rehydrated mushroom slices

4.10 Optimization of dehydration process

The sensory analysis suggested that blanched and sulfited sample was found to be best with respect to the quality parameters like moisture content, drying time, Yield, rehydration ratio, rehydration coefficient, percent water in rehydrated material, and non-enzymatic browning. The sample also produced best result with respect to the sensory parameters like color, flavor and overall acceptance. Thus, blanching and sulfating treatment (85°C and 0.3%) for dehydration of Oyster mushroom at 60°C in a cabinet dryer was found to be optimum for the best quality product within the range of study. The best predictive model for the dehydration of Oyster mushroom was found to be exponential model with equation $y=6.495e^{-0.01x}$ with the coefficient of determination (R^2) is 0.935 for blanched and sulfited sample.

Part V

Conclusions and recommendations

5.1 Conclusions

From the research work, following conclusions can be made:

(1) Mushroom can be dehydrated to relatively acceptable level with suitable pretreatments.

(2) The pretreatments viz., blanching, sulfating and blanching and sulfating had significant effect on different physic-chemical and overall acceptability of the dried mushroom.

(3) The present study revealed that mushroom can be dehydrated to acceptable dried product with blanching at 85°C for 3 minutes and sulfating in 0.3% KMS solution for 10 minutes followed by cabinet drying.

(4) The drying time of 5 hrs is sufficient to bring the product to stable moisture content i.e. less than 6% in cabinet dryer.

(5) The best predictive model for the dehydration of Oyster mushroom was found to be Exponential model of equation $y=6.495e^{-0.01x}$ and the coefficient of determination (R^2) is 0.935 for blanched and sulfited sample.

(6) Since, the product which was blanched and sulfited had maximum RR, maximum sensory score for color, flavor and overall acceptability; it can be commercialized.

5.2 Recommendations

(1) Storage stability of dried mushroom with various packaging material and storage environment can be carried out because dried mushroom is hygroscopic in nature.

(2) Mathematical modeling of dehydration process at various temperatures, types of dryer, pre-treatments and various air velocities can be carried out.

(3) The retention of nutrients in mushroom affected by various process conditions can also be studied.

Part VI

Summary

Oyster mushroom, "*chyau"* is widespread in temperate and subtropical forests throughout the world. It is a saprotroph that is a primary decomposer of wood, straw etc. Of the hundreds of edible mushroom varieties *Agaricus* (button), *Lentinus* (shittake), *Pleurotus* (Oyster), *Volvariella* (paddy straw) etc. are most popular edible mushroom throughout the world. Among the most popular varieties of mushroom *Pleurotus sajor* caju (Indian Oyster mushroom) was collected from Simadiya VDC- 8 of Sunsari, Nepal for the study.

The mushroom was dried in a cabinet dryer at 60^{o}C to the moisture content of 6% or less after the preliminary operation and various pretreatments. The various pretreatments used are blanching (85^{o}C for 3 min), sulfiting (0.3% KMS for 5 min) and blanching and sulfiting. Among the treatments, blanching and sulfitation showed the best results in terms of moisture content (4.58%), length of drying time (5hrs), final product Yield (83.94%), RR (3.12), PWRM (75.2%), NEB (0.189) and overall acceptability. While it fails to produce the same result in terms of RC and vitamin C content.

The statistical analysis was carried out for ANOVA to reveal the effect of pre-treatments on different parameters and sensory score of the products. The statistical analysis showed significant effect of pretreatments on sensory score for color, taste, appearance and overall acceptability except flavor. The effect of pretreatments on parameters like moisture content of dried product, RC, PWRM and NEB were not significantly different while RR, vitamin C and yield were significantly different at 5% level of significance.

Among the four different samples the blanched and sulfited sample was best in terms of various quality attributes. The blanched and sulfited sample showed the least moisture content (4.58%) and drying time (5hrs). It showed better dehydration characteristics, highest RR (3.12), RC (0.398), PWRM (75.2%) etc. The mean sensory score was also consistently the highest for the blanched and sulfited sample. Since, the superiority table suggested blanched and sulfited sample the best; it is chosen as the best treatment. The best predictive model for the dehydration of Oyster mushroom with blanching and sulfating as pretreatment was found to be exponential model. The predictive of equation for the best product was, $y=6.495e^{-0.01x}$ with coefficient of determination (R^2) 0.935.

Part VI

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Appendices

Appendix A

Sensory evaluation card

Sensory evaluation for mushroom dried under different pre-treatments

Nine point hedonic scale rating test

Name of the product: Rehydrated mushroom pieces Date:

Name of the panelist:

Observe the product by tasting. Use appropriate scale to show your attitude by checking at the point that best describes your feeling of the products. Write if any comments. An honest expression of your feeling will help me.

Parameters	A	B	C	D
Color				
Flavor				
Taste				
Appearance				
Overall				

Comments if any

……

……

……... …….

Signature……

Scaling points

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 extremely

Sensory analysis of the samples

Table A.1 Raw data of the sensory evaluation of four samples

Treatment	Panelist	Color	Flavor	Taste	Appearance	Overall
Fresh	1	7	7	7	7	7
Fresh	2	7	5	6	7	7
Fresh	3	7	4	7	6	6
Fresh	4	8	8	9	8	8
Fresh	5	6	4	5	7	5
Fresh	6	8	6	7	7	7
Fresh	7	8	8	7	8	8
Fresh	8	7	8	7	6	6
Fresh	9	7	8	6	7	7
Fresh	10	7	7	7	7	6
Blanched	1	4	5	3	5	5
Blanched	2	6	6	5	5	5
Blanched	3	6	5	6	5	5
Blanched	4	6	7	8	6	6
Blanched	5	4	2	3	4	5
Blanched	6	4	3	3	4	5
Blanched	7	7	7	7	7	7
Blanched	8	4	1	2	5	5
Blanched	9	4	2	1	5	6
Blanched	10	5	3	4	5	6

Treatment	Panelist	Color	Flavor	Taste	Appearance	Overall
Sulfited	1	5	5	4	5	5
Sulfited	2	7	6	5	6	6
Sulfited	3	8	3	3	4	6
Sulfited	4	7	7	7	6	6
Sulfited	5	5	3	4	5	5
Sulfited	6	5	7	4	6	6
Sulfited	7	7	6	6	7	7
Sulfited	8	7	7	5	6	6
Sulfited	9	6	6	6	7	7
Sulfited	10	7	6	5	6	6
B and S	1	6	6	6	6	6
B and S	2	8	8	8	8	8
B and S	3	6	5	6	5	5
B and S	4	5	5	6	7	6
B and S	5	7	5	6	6	6
B and S	6	7	4	6	8	6
B and S	7	9	8	8	8	8
B and S	8	9	7	7	7	8
B and S	9	9	8	7	8	8
B and S	10	8	6	6	7	7

Dehydration data for the samples

Table A.2 Raw data of dehydration of mushroom samples

Moisture content (kg/kg dry matter)				
Time	Fresh	Blanched	Sulfited	Blanched and sulfited
0	10.36	10.9	11.02	10.52
30	6.71	6.3	6.12	5.92
60	4.76	2.4	2.77	2.71
90	2.41	0.9	1.061	1.11
120	2	0.68	0.44	0.37
150	1.52	0.366	0.24	0.225
180	1.31	0.26	0.224	0.156
210	1.078	0.17	0.204	0.126
240	0.88	0.094	0.176	0.106
270	0.552	0.069	0.067	0.064
300	0.32	0.063	0.062	0.055
330	0.181			
360	0.064			

Drying curves for different samples

Figure A.1 Drying curve for fresh (non-treated) sample

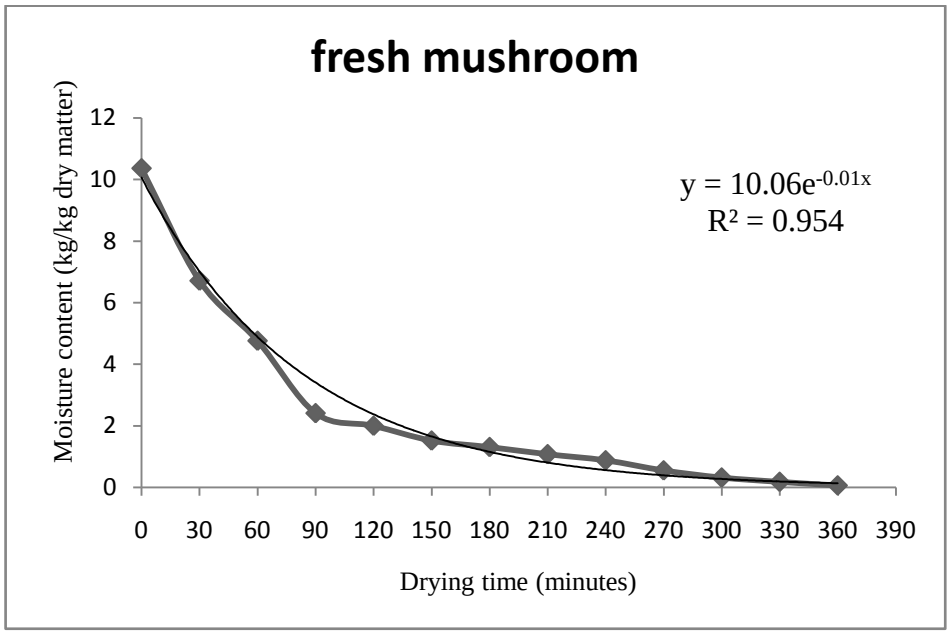


Figure A.2 Drying curve for blanched sample

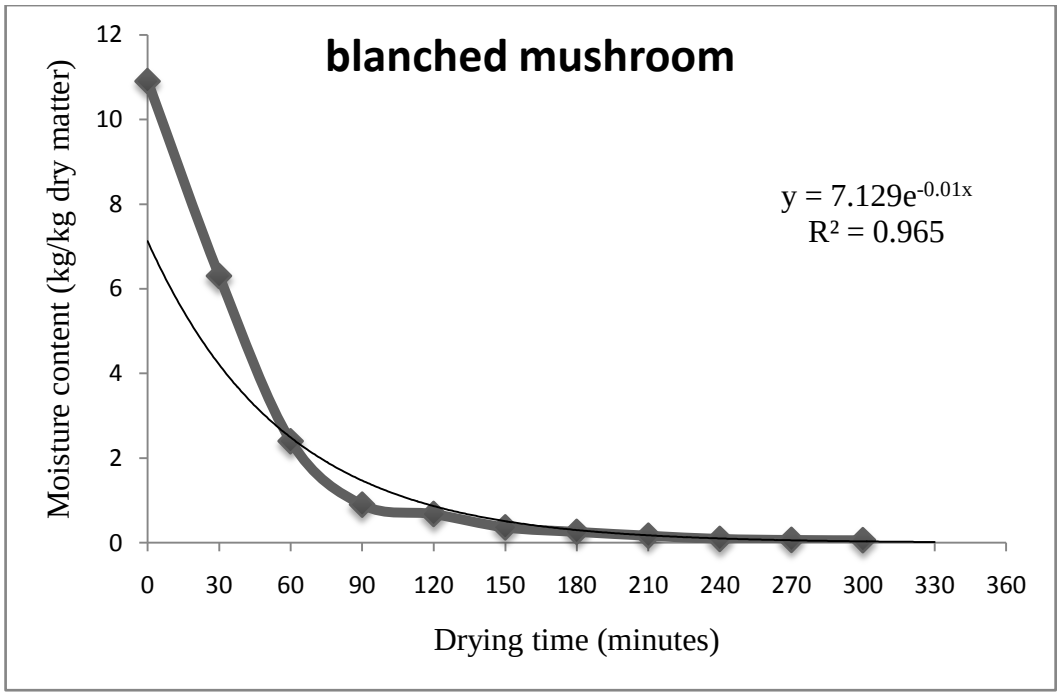


Figure A.3 Drying curve for sulfited sample

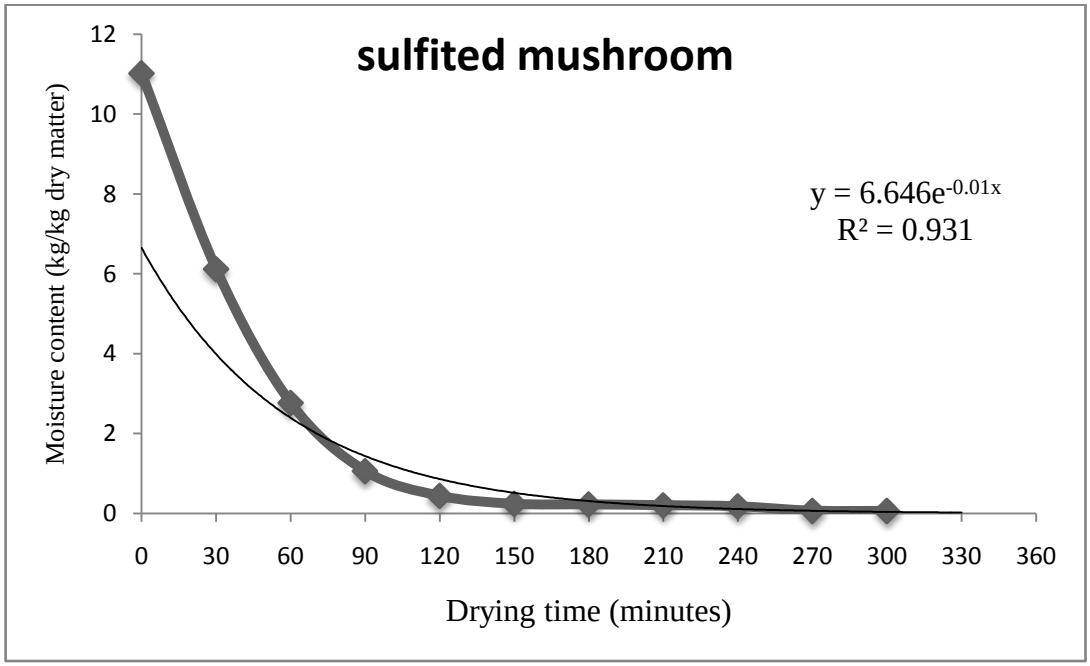
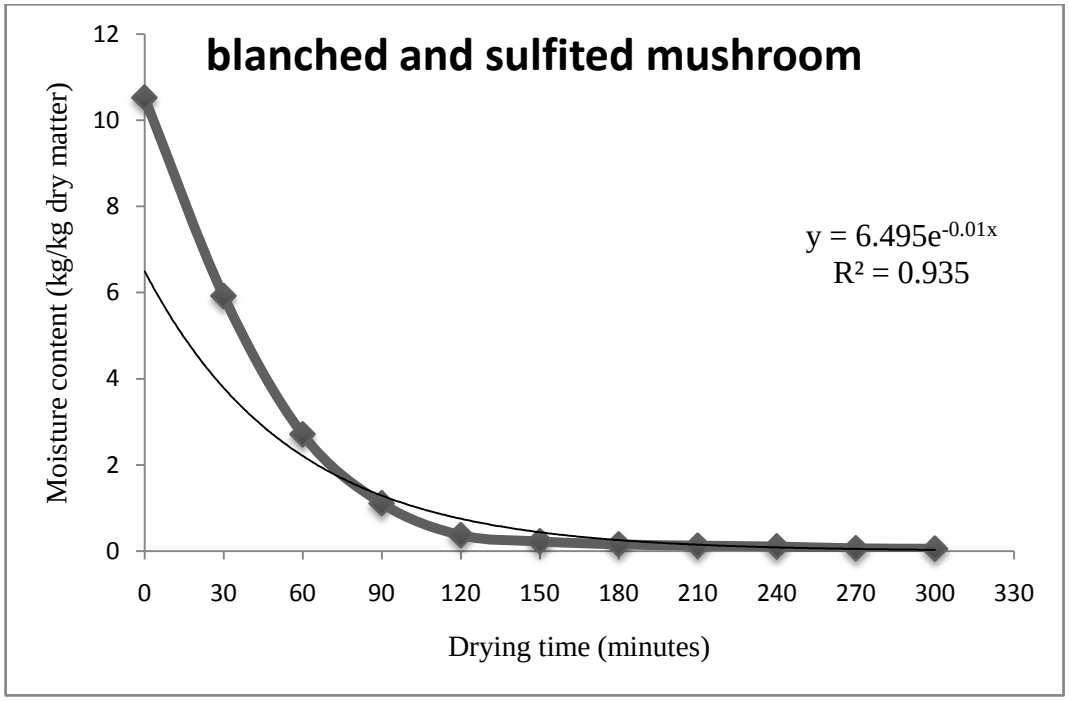


Figure A.4 Drying curve for blanched and sulfited sample



Appendix B

ANOVA results

Sensory evaluation of dried Oyster mushroom

Table B.1 Two way ANOVA (no blocking) for color as variate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	35.6	11.867	11.69	<.001
Panelist	9	17	1.889	1.86	0.102
Residual	27	27.4	1.015		
Total	39	80			

LSD at 5% level of significance for treatment= 0.924

Table B.2 Two way ANOVA (no blocking) for flavor as variate

Source of variation	d.f.	s.s.	m.s.	v.r	F pr.
Treatment	3	34.2	11.4	4.94	0.007
Panelist	9	45.1	5.011	2.17	0.058
Residual	27	62.3	2.307		
Total	39	141.6			

LSD at 5% level of significance for treatment= 1.394

Table B.3 Two way ANOVA (no blocking) for appearance as variate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	26.475	8.825	23.19	<.001
Panelist	9	18.225	2.025	5.32	<.001
Residual	27	10.275	0.38		
Total	39	54.975			

LSD at 5% level of significance for treatment= 0.566

Table B.4 Two way ANOVA (no blocking) for overall acceptance as variate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	19.40	6.4667	13.86	<.001
Panelist	9	21.60	2.4000	3.14	0.064
Residual	27	12.60	0.4667		
Total	39	53.60			

LSD at 5% level of significance for treatment= 0.627

Table B.5 Two way ANOVA (no blocking) for taste as variate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
treatment	3	48.875	16.292	10.50	<.001
panelist	9	32.625	3.625	2.31	0.053
Residual	27	41.875	1.551		
Total	39	123.375			

LSD at 5% level of significance for treatment= 1.143

Rehydration properties of Oyster mushroom

Table B.6 One- way ANOVA for rehydration ratio (RR) as variate

Time	d.f.	s.s.	m.s.	v.r.	F.pr.
Treatments	3	0.362	0.120	21.53	<.001
Residual	8	0.044	0.005		
Total	11	0.407			

LSD at 5% level of significance for RR= 0.141

Table B.7 One- way ANOVA for rehydration coefficient (RC) as variate

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr.
Treatments	3	0.0056	0.0018	3.54	0.068
Residual	8	0.0042	0.0005		
Total	11	0.0099			

LSD at 5% level of significance for treatment= 0.043

Table B.8 One- way ANOVA for % water in rehydrated mushroom (PWRM) as variate

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr.
Treatments	3	37.4	12.12	2.28	0.156
Residual	8	43.85	5.81		
Total	11	81.39			

LSD at 5% level of significance for treatment= 4.408

Table B.9 One- way ANOVA for Vitamin C (ascorbic acid) as variate

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr.
Treatments	3	182.280	60.76	21.23	<.001
Residual	8	22.895	2.86		
Total	11	205.175			

LSD at 5% level of significance for treatment= 3.185

Table B.10 One- way ANOVA for Non-enzymatic browning (NEB) as variate

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr.
Treatments	3	0.030	0.0102	7.5	0.010
Residual	8	0.011	0.0013		
Total	11	0.042			

LSD at 5% level of significance for treatment= 0.069

Drying time of Oyster mushroom during the dehydration process

Table B.11 One- way ANOVA for drying time as variate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatments	3	3.75	1.25	15	0.001
Residual	8	0.667	0.08		
Total	11	4.416			

LSD at 5% level of significance for treatment= 0.543

Moisture content of Oyster mushroom after the dehydration

Table B.12 One- way ANOVA for moisture content of mushroom as variate

Sources of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F.pr.
Treatments	3	0.405	0.135	2.81	0.172
Residual	4 (4)	0.192	0.048		
Total	7 (4)	0.463			

LSD at 5% level of significance for treatment= 0.497

Yield of the dehydrated mushroom

Table B.13 One- way ANOVA for Yield of the dehydrated mushroom as variate

Sources of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F.pr.
Treatments	3	4.304	1.434	15.88	<.001
Residual	8	0.722	0.090		
Total	11	5.026			

LSD at 5% level of significance for treatment= 0.5

Appendix C

Photo gallery