Drying and storage studies in nutmeg

(*Myristica fragrans* Houtt.)

By

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(2011-12-114)

THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Drying and storage studies in nutmeg (*Myristica fragrans* Houtt.)"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title of any other University or Society.

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ABBREVIATIONS

g	gram
cfu	Colony Forming Units
et al.	Co workers
MAS	Months After Storage
SD	Sun Drying
MD	Mechanical Drying
BD	Bulb Drying
OD	Country Oven Drying
ppm	Parts per million
RH	Relative Humidity
RM	Residual Moisture
sp. or spp.	Species
viz.	Namely
db	Dry Basis
min	Minutes

INTRODUCTION

1. INTRODUCTION

India is also known as ‘Land of Spices’, where each state cultivates one or the other spices and Indians use them generously in their culinary preparations as well as in traditional medicines. Only nine per cent of our spice production is exported to more than 100 countries and remaining are consumed internally. India commands a formidable position in the world spice trade with 45 per cent share in volume and 30 per cent in value. The major destination of Indian spice exports during 2005-06 are USA followed by Malaysia, UK, China, Germany, Japan, UAE, Sri Lanka and Singapore.

Tree spices, as the name indicates, are tall plants with more canopies compared to other spices like rhizomatous spices, seed spices, herbal spices and ‘nutmeg’ is one among the seventeen tree spices grown in different parts of India. Tree spices are best components suitable for agro-forestry systems particularly coconut based system. The tree spices like clove, nutmeg, tamarind, cinnamon and tejpat are relatively more important and they are grown in an area of 81,189 ha with a production of 2,08,445 tonnes (DASD, 2007).

Nutmeg (*Myristica fragrans* Houtt.) is unique among the tree spice plants as it produces two commercial spice products namely, nutmeg and mace. It belongs to the family Myristicaceae, comprising of 19 genera and about 400 species. Nutmeg is the dried seed, while mace is the aril covering the outer surface of the seed. The yield of the mace is about 15 per cent that of nutmeg and it is more expensive among the two spices. The spice is widely used as a condiment and also in medicine. In India, nutmeg and mace are used more as drugs than as condiments due to their valuable medicinal properties. Mace is chewed for masking foul breath (Pruthi, 1979).

The nutmeg fruit resembling a large apricot is usually pendulous and 6 to 9 cm long. When ripe, the succulent, aromatic yellow pericarp splits into two halves exposing the purplish brown mace and shiny testa. An individual nutmeg seed weighs about 5 to 10 g, while the aril (mace) weighs 1 to 4 g. The ratio of nut to mace in nutmeg is 20:3 (Purseglove *et al*., 1981).

During 2004-05, India exported 1,250 tonnes of nutmeg and mace to the value of Rs. 2235.00 lakhs. Under Indian conditions, the production potential is very low i.e., 800 kg nutmeg and 125 kg mace/ha and the present production is not sufficient to meet the domestic requirement. The mace, which is brilliant red in colour is somewhat tough and leathery (Thangaselvabai *et al*., 2011).

Nutmeg the “two in one spice” is valued for its flavouring and medicinal properties. It is native of Moluccas Island and in India it is cultivated throughout Kerala, parts of Tamil Nadu, Karnataka, Goa, Assam and Andaman and Nicobar Islands in an area of 15,131 ha with a production 11,424 tonnes of spice. India also imports 1,325 tonnes of nutmeg and 265 tonnes of mace (Haldankar and Rangwala, 2009).

Dried nutmeg and mace are of great importance in international trade and are used in the preparation of its extractives and volatile oils. The pale yellow essential oil which is volatile fraction obtained by steam distillation is used as a flavouring essence and in perfumery.

Drying to optimum moisture level without losing the inherent qualities especially the colour is a prerequisite for long storage and better price. Colour plays an important role in deciding the commercial value of mace and it has been established that its scarlet red colour is due to the pigment lycopene (Gopalakrishnan *et al*., 1980).

The keeping quality of spices depends much on drying and moisture content which should be kept between 10 and 12 per cent for most of the spices for better storage (Pruthi and Krishnamurthy, 1985). Even one percentage more than critical moisture level may affect the quality of mace. The most important parameter in drying is the temperature and time of exposure and this may vary with the end use of the product. During drying, the mace loses about 60 per cent of its weight as moisture (Gopalakrishnan, 1992). If drying is delayed, mace becomes highly susceptible to mould and insect contamination.

The appearance, the contents of volatile oil and oleoresin, the pungency level and a subjective assessment of the aroma and flavour are important in the quality evaluation of dried nutmeg and mace. The relative importance of these aspects is dependent upon the end use of the spice. A number of factors at both the preharvest and post harvest stages can have a significant influence on the quality of the dried product.

Conventionally, mace is dried in the sun or in kitchen fire place utilizing the heat from the stove. Conventional methods of drying result in loss of some volatile oil by evaporation and destruction of some of the heat sensitive pungent constituents. It is also difficult to control the temperature of drying. Temperature has a profound influence on the colour of the dried mace. Conventionally dried mace does not possess uniform red colour.

Although sun drying is common, it is difficult and very slow in many areas because of the active monsoon during the harvesting season and also sun drying bleaches the colour and contaminates mace with mould growth resulting in its poor appearance. Therefore, importance is given to mechanical drying, which is cost effective and gives a consistent high quality product. This method of drying could produce a uniformly clean product, with the maximum retention of volatile oil.

After the processing of spices, proper packaging and storage is important as the spices and spice products are hygroscopic, which results in absorption of moisture and as a result of this, the product becomes lumpy and microbial load will also increase thus decreasing the product quality. Frequent aflatoxin contamination due to *Aspergillus sp.* is found in many spices like nutmeg, chillies and the products exported were being rejected by the importing countries like European Union. In view of these problems, it was proposed to carry out a study entitled "Drying and storage studies in nutmeg (*Myristica fragrans* Houtt.)" with the following objectives:

1. To find out an effective pretreatment method to reduce the microbial load.
2. To develop a suitable drying technique for both nutmeg and mace.
3. To develop a suitable packaging material and storage method for long term retention of quality.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Nutmeg, a native of Moluccas Island, is the dried seed of the peach like ripe fruit of *Myristica fragrans* Houtt. which yields two spices viz. nut and mace. It is a highly economical tree spice, which plays major role in economics of countries like Indonesia and Grenada. Nutmeg belongs to the family Myristicaceae, with about 18 genera and 300 species. The genus *Myristica* is distributed from India and South-east Asia to North Australia and the Pacific Islands. Nutmeg has its origin in the Spice Islands of Indonesia. The name nutmeg is derived from the Latin word *nux muscatus*, meaning 'musky nut'. Two important spices derived from the fruit are – nutmeg and mace (Leela, 2008).

A review of research works done on different aspects of nutmeg was undertaken and presented here under the titles.

2.1 Composition and uses of nutmeg

2.2 Harvesting and post harvest processing of nutmeg

2.3 Pretreatment studies

2.4 Drying studies in spices and herbs

2.5 Packaging and storage studies in spices

2.1 COMPOSITION AND USES OF NUTMEG

2.1.1 Composition of nutmeg and mace

Pruthi (1979) reported that the principal constituents of nutmeg are fixed oil, volatile oil and starch. It also contains protein, cellulose, pentosans, resin and mineral elements. The percentage of constituents differs between the spices and this is due to geographical origin, quality and duration of storage and even growing locations. The flavour and therapeutic actions are due to the volatile oil.

Table 2. 1. Proportion of different parts of nutmeg fruit

Sl.No	Particulars	Weight (g)
1	Average weight of the fruit	46.14 (100%)
2	Average weight of the seed with mace	7.38 (15.99%)
3	Average weight of mace	1.47 (3.19%)
4	Average weight of seed	5.97 (12.81%)
5	Average weight of rind	38.77 (84.01%)

(Source: Joshi *et al.*, 1996)

Table 2. 2. Products from *Myristica fragrans*

Sl. No	Product	Quantity
1	Nutmeg	7 to 10 kg/10 year old tree
2	Mace	1 to 2 kg/10 year old tree
3	Mace oil	4 to 17 per cent
4	Nutmeg oil	5 to 15 per cent
5	Leaf oil	0.34 to 0.65 per cent
6	Nutmeg oleoresin	31 to 37 per cent
7	Mace oleoresin	27 to 32 per cent
8	Nutmeg butter	25 to 40 per cent

(Source: Krishnamoorthy and Rema, 2011)

Nutmeg is reported to contain moisture (14.3%); protein (7.5%); ether extract (36.4%); carbohydrates (28.5%); fibre (11.6%); mineral matter (1.7%); calcium (0.12%); phosphorus (0.24%) and iron 4.6 mg/100 g. It contains volatile oil (6-16%); starch (14.6-24.2%); pentosans (2.25%); furfural (1.5%); and pectin (0.5–0.6%).

Nutmeg volatile oil is comprised of a mixture of terpenes and alkenylbenzene derivatives. Myristicin, safrole and elimicin constitute about 80 percent of the alkenylbenzene derivatives. Alkaloids, saponins, anthraquinones, cardiac glycosides, flavonoids and phlobatanins were also detected in the aqueous extract of *M. fragrans* (Olaleye *et al*., 2006). Myristicin is responsible for the hallucinogenic effect of nutmeg. Bioactive compounds including camphene, eugenol, isoelemicin, isoeugenol, methoxyeugenol and elimicin were identified as the main constituents of *M. fragrans* seed essential oil (Chirathaworn *et al*., 2007). The commonly known phytochemical compounds of *M. fragrans* are volatile substances, terpenoids, phenolics, lignin compounds, protein, mucilage and starch.

Mace is also aromatic and its aroma is due the presence of terpenes. Depending on its origin, mace has 7 to 14 per cent essential oil and about 30 per cent fixed oil. It contains the same aroma compounds as nutmeg but in different amounts, mainly monoterpenes (87.5%), monoterpene alcohols (5.5%) and other aromatics (7.0%). Like nutmeg essential oil, the main constituents of mace essential oil are sabinene, α-pinene, myrcene, limonene, 1,8-cineole, terpinen-4-ol, myristicin, γ-terpinene and safrole (Pooja *et al*., 2012).

2.1.2 Uses of nutmeg

The nutmeg is providing two spices, i.e. the nutmeg (dried seed) and the mace (dried aril covering the seed). Nutmeg and its oleoresins are used in the preparation of meat products, soups, sauces, baked foods, confectioneries, puddings, seasoning of meat and vegetables, to flavour milk dishes and punches.

Mace is used to flavour milk based sauces and processed products like sausages, soups, pickles, ketchups, chutneys etc. Nutmeg oil and mace oil are used mainly in flavouring soft drinks, canned foods and meat products (Pruthi, 2006).

Nutmeg is widely popular in Europe and India for its flavouring and medicinal properties. The spice nutmeg is the dried kernel of the seed and mace is the dried aril surrounding it. Both the spices have similar flavour. However, nutmeg is reported to be slightly sweeter than mace and is more preferred in food. Besides nutmeg and mace, a number of other products, namely oleoresin, nutmeg butter and essential oils, are also derived from *M. fragrans*. These value-added products find varied use in the food, medicine and perfume industries. It may soon be possible to manage the serious condition of diabetes naturally using nutmeg seeds, according to new research presented at the British Pharmaceutical Conference in Manchester. In some tribal areas of India, as a part of conventional medicine, nutmeg is used for treating diabetes, as well as other ailments such as diarrhoea, mouth sores, and insomnia (Nair, 2011).

Nutmeg proves to be an excellent tonic for the cardiovascular system. It increases the blood circulation and stimulates the heart functions. Nutmeg oil is a great liver tonic, as it can remove the toxins therein. Myristicin, the active principle of nutmeg, has demonstrated extraordinary effects in the protection of hepatocytes or liver cells. It is helpful in treating kidney infections and dissolves kidney stones also. Nutmeg is widely used in cough syrups also. It is also antiseptic in nature and hence it is used in many kinds of toothpaste. Research supports the use of nutmeg as a preservative and an anti-septic (Krishnamoorthy and Rema, 2011).

2.2 HARVESTING AND POST HARVEST PROCESSING OF NUTMEG

2.2.1 Harvesting and yield of nutmeg

A seedling tree begins to bear fruits when five to eight years old. Trees propagated vegetatively by marcotts or inarching fruit earlier. Yield gradually increases with age of the plant up to 15 years or longer and continues for 30 to 40 years and there after it stabilizes. The fruit ripen in about six to nine months after flowering, usually with two peaks of fruiting annually, although some fruits ripen at all times. Harvesting commences in June and continues up to August. Fruits are ripe and ready for harvest when the pericarp splits open. Harvesting is generally done by a knife attached to a stick known as bill hook. Individual fruits weigh on an average of 60 g of which the seed weigh (6-7 g), mace weigh (3-5 g) and rest is pericarp (Mathew, 2008).

2.1.2 Post harvest processing

The fruits may be harvested from the tree after splitting, but more usually are gathered after falling on the ground once in every few days. If it is allowed to lie on the ground for several days, the underside of the kernel will become dark and discoloured and the hazard of mouldiness is increased. During drying, nutmeg loose about 25 per cent of weight (Koshy, 2003).

Mechanical and fire wood based driers can be used for drying both nutmeg and mace. Temperature is the only criteria which judge the quality of the dry produce. In case of drying nutmeg, around 40^0C may be adopted and continuous drying may be avoided. Care should be taken to see that the shell is neither broken nor the nutmeg oil oozes out. This is due to the increased temperature during drying. Both nutmeg and mace need to be dried to a safe moisture content of 9 to 10 per cent (Jayashree and Chempakalam, 2011).

2.3 PRETREATMENT STUDIES

Drying is the most widely used primary method of food preservation. Blanching is carried out to inactivate natural enzymes in order to improve color and texture of the product. Blanching has been found to enhance the drying rate of chillies due to cell wall destruction (Turhan *et al*., 1997).

Nutmegs are shelled by machine in the countries producing nutmeg on a large scale. The kernels are treated with lime before export to give them a good colour and to prevent insect damage (Shanmugavelu *et al*., 2002).

According to Dandamrongrak (2003) blanching is an important step in fruit and vegetable processing because of many advantages that can be obtained. An important role of blanching is to inactivate enzymes and increase the drying rate.

Studies at Indian Institute of Spices Research (IISR), Calicut showed that blanching could reduce the microbial load by 75 to 90 per cent (Dhas and Korikanthimath, 2003).

The time required to dry unblanched mace from an initial moisture content of around 186.5 per cent db (dry basis) to the final moisture content of around 5.2 per cent db was 330, 240 and 210 min at 50, 55 and 60^0C of drying air temperature, respectively. In case of blanching, the time required was 300, 210 and 180 min for the above temperatures respectively. It was reported that unblanched and blanched mace dried in 4 hours and 3.5 hours, respectively in an agricultural waste fired dyer at average drying temperature of 50^0C (Dhas *et al.*, 2004).

Hot water blanching (5 minutes at 97^0C) was found to be suitable for banana before subjecting to drying (Kar *et al.*, 2003). Blanching nutmeg mace in

75^0C hot water for two minutes decreased the drying time by 12.5 per cent (Heartwin *et al.,* 2004).

2.4 DRYING STUDIES IN SPICES AND HERBS

Water is a significant component of biological materials. The physical and chemical properties of herbs are determined by their moisture content. The first step in many post harvest operations is the removal of water through drying.

Drying is the oldest preservation technique of herbs and spices. In developing countries, traditional sun drying method is commonly used for drying herbs and spices. Although it is the cheapest method, the dry products are of poor quality due to contamination by insects, birds and dust.

Drying is generally done to decrease the moisture content so as to minimize the microbial contamination and retaining the quality parameters at its maximum. Percentage moisture content of wet nutmeg varies between 42 to 50 per cent and that of mace from 32 to 36 per cent. Various methods of drying nutmeg are in vogue, but sun drying and mechanical drying are the most common in Kerala.

Drying to optimum moisture level without losing the inherent qualities especially colour is a prerequisite for long storage and better price. Colour plays an important role in deciding the commercial value of mace and that its scarlet red colour is due to the pigment lycopene. This pigment is highly sensitive to heat and light. During drying, scarlet red colour of mace changes to light red or reddish brown colour. Hot air mechanical drying is a viable alternate technology for curing mace. A mild blanching and subsequent drying of mace at 50^0C in a cross flow dryer helped in retention of colour and general quality of mace. Mace has to be dried to five per cent level for which it takes about 16 hours under open sun, 24 to 28 hours under shade and five to six hours in mechanical drying. (Gopalakrishnan *et al*., 1980).

Adverse drying conditions such as higher temperature during drying leads to several irreversible chemical and biological reactions in food, accompanied by several structural, physical and mechanical modifications. These include degradation of colour, case hardening, lowering of sensory quality, inactivation of bacteria and enzymes, loss of nutrients, aroma and change of shape and texture (Abid *et al.,* 1990).

The major objective in drying agricultural products is the reduction of the moisture content to a level which allows safe storage over an extended period. Drying also brings about substantial reduction in weight, volume and minimizes packaging and storage requirement and also reduces the transportation costs (Okos *et al.,* 1992).

Mace is detached from the seed shell by hand or with a knife, washed and flattened out by hand or between boards and dried slowly for 10 to 14 days. During drying, mace gradually becomes brittle, turning from scarlet red or orange to yellowish brown and it acquires the pungent aroma. Hot air ovens can be used to dry the mace at 50^0C for retention of better colour and getting a good product. Blanching of mace in hot water at 75^0C for two minutes is advantageous to get a glossy, pleasing product, free from fungal and insect infection with more retention of colour (Dhas *et al*., 2004).

Drying decreases water activity which ultimately retards the microbial growth and helps to conserve the desirable qualities and reduces the storage volume. However enzymatic and or non enzymatic processes that may occur during drying of the fresh plant tissues may lead to significant changes in the phytochemical composition (Capeka *et al.,* 2005).

According to Schmidt *et al*. (2005) inadequate drying leads to microbial contamination and changes in the phytochemical composition.

According to Cheng *et al.* (2006) drying is one of the oldest food preservation techniques and it can be carried out at different temperatures and Relative Humidity (RH) conditions. The removal of moisture from food retards many of the moisture-mediated deteriorative reactions and prevents the growth and reproduction of micro organisms.

The quality of nutmeg and mace depends to a large extent upon the post harvest operations. The post harvest operations in nutmeg include separation of nut and mace, washing, drying, cleaning, sorting, grading and packaging. Care has to be taken in each of these process as these operations help in the conservation of the basic qualities like aroma, flavour, pungency, colour, appearance etc. of nutmeg and mace for which they are valued. Among the various operations drying remains the most important step (Krishnamoorthy and Rema, 2011).

Most of the herbs and spices are marketed as dried, because, due to high water content in the fresh state they undergo severe deterioration after microbial growth and biochemical changes (Verma and Chauhan, 2011).

2.4.1 Sun drying

Sun drying is the cheapest method of drying which has been practised since ancient times. Here drying process is slow and the product will develop dark colour and may often contain deposits which may reduce their market value. The rate of drying depends on the temperature during the season. It is slower during winter when the day temperature ranges from 20 to 25°C than in summer with 35 to 42°C (Gupta and Pareek, 1993).

Pragathi and Dahiya (2003) found that indirect solar drying method was comparatively better than direct solar drying in terms of nutritional value of dried aonla fruit.

Zachariah *et al*. (2004) reported that mace was usually dried in the sun on large trays or mats which can quickly be carried to shelter if it rains and at night, as increased humidity will spoil its quality. As the harvesting season comes under monsoon season, it is very difficult to dry the mace in sun drying. Also it is difficult to control the temperature of drying, which has profound influence on the colour of the dried mace. The dried mace so obtained does not possess uniform red colour. Also about two to three per cent of the mace gets charred in the process. Sun drying bleaches the colour and contaminates mace with mold growth ending in poor appearance. Hence sun drying is not an ideal practice.

Solar driers were used successfully in drying of spices and medicinal plants. Those driers may reduce the drying time by 65 per cent compared to natural drying (Mohamed *et al*., 2005).

According to Doymaz (2005) sun drying is one of the most common methods used in the tropical and subtropical countries but it is extremely weather dependent and the product is more susceptible to contamination. It is difficult to control drying rates, hence product quality during sun drying is adversely affected.

Drying is the oldest preservation technique of herbs and spices. In developing countries, traditional sun drying method is commonly used for drying herbs and spices. Although it is the cheapest method, the dry products are of poor quality due to contamination by insects, birds and dusts. In the case of Thailand, most of herbs and spices are still dried using traditional sun drying method. Due to rewetting of the products during drying by rain and also because of too slow drying rate in the rainy season, toxic substances such as an aflatoxin produced by moulds is often found in the dry products. This is one of the main problems, which restricts the growth of exports of herbs and spices to international markets (Janjai *et al.*, 2008).

In Kerala the harvesting season coincides with the monsoon season. So sun drying often becomes impossible. Freshly harvested mace can be blanched in water at 75^{o}C for two minutes to retain the scarlet colour. This is followed by hot air drying at 55-65^{o}C which takes about three to four hours for drying to a moisture level of 8 to10 per cent (Anandaraj *et al*., 2005).

Nutmeg is harvested during peak monsoon season and hence sun drying becomes difficult. However, sun drying is a common method practiced in Kerala. Both the nut and mace dried separately as the drying characteristics of both are different. Mace is detached from the nut carefully soon after harvest, washed and then sun dried until they become brittle. The scarlet coloured mace gradually becomes yellowish brown and brittle when drying is completed. The unshelled nutmegs are dried in the sun until the seeds inside rattle on shaking (Krishnamoorthy and Rema, 2011).

2.4.2 Smoke Drying

Pruthi (1979) stated that farmers dry the mace by smoke or in kitchen fire place utilizing the heat from the stove. The dried mace obtained by these methods does not possess good appearance and there is loss of volatile oil content.

Nair (1994) reported that drying of mace was carried out in the Agricultural Waste Fired Dryer (AWFD). The dryer has a burning-cum-heat exchanger, plenum chamber and drying zone. The cylindrical burning cum heat exchanger is located at the center of the plenum chamber. One end of the heat exchanger is connected to the chimney. The heat from the burning chamber is transferred by radiation and convection to the surrounding air moving up from the bottom. Firewood is burnt in the heat exchanger as and when required to keep the fire burning. The dried mace obtained by this method possess good appearance and there is no loss of volatile oil content.

2.4.3 Mechanical drying

To overcome the problems of drying viz. unhygienic surroundings and long duration of drying, the mechanical drier appeared in to the drying scenario.

In the air circulating type of electric dehydrators, temperature inside the chamber can be precisely controlled to obtain desired quality of product without spoilage and dependence on weather in a short period of time.

Correct drying is done to reduce the moisture content upto 5 to 10 per cent, to minimize the spoilage. Drying temperature has vital influence on quality. In artificial drying, the temperature should not exceed 40°C, as the essential oil and flavour are lost at high temperature (Atal and Kapoor, 1982).

According to Kachru *et al.* (1989) mechanical drying at 50^0C was found to be a quick process, yielding a superior quality nutmeg compared to shade and sun drying.

According to Joy *et al.* (2000) physico-chemical quality analysis of the nutmeg dried in tunnel drier gives good quality nutmeg over the commercially available samples (sun dried). Overall quality of the spice is also improved through the drying in solar tunnel dryer.

Sefidkon *et al.* (2006) evaluated the influence of three drying methods viz. sun drying, shade drying and oven drying at 45°C on yield and chemical composition of the essential oil of *Satureja hortensis.* It could be concluded that drying of aerial parts of *S. hortensis* in the oven at 45°C is most suitable and is recommended for fast drying, high oil yield as well as for a high percentage of carvacrol.

Central Plantation Crop Research Institute, Kasaragod, Kerala has developed a small dryer suitable for drying mace which has burning cum heat exchanger and drying chamber. Mace is spread in single layer over the wire mesh separating the plenum and drying chamber. The temperature of drying is maintained around 50^0C. Hot air requires four hours to complete the process. The moisture content, volatile oil and oleoresin in dried mace range from 4.85 to 5.05 per cent, 11.57 to 12.40 per cent and 21.25 to 22.57 per cent, respectively (Parthasarathy *et al*., 2008).

According to Athmaselvi (2009) drying turmeric rhizomes in a mechanical drier at 60°C showed higher percentage of curcumin, oleoresin and essential oil contents than drying under the sun (29-34°C).

In *Sechium edule* (chayote) dehydration at 55°C and 65°C yielded better quality product as assessed from the time of drying, colour changes, reconstitution and sensory acceptability (Sharma and Verma, 2010).

Phoungchandang and Saentaweesuk (2011) reported that drying reduces the moisture content and hence inhibits microbial growth and certain biochemical changes, but leads to loss of aroma in ginger.

2.5 STORAGE STUDIES

2.5.1 Packaging and storage of mace and nutmeg

Nutmeg from West Indies, Greneda and Indonesia is packed in 50 to 60 kg capacity double jute sacks. In Sri Lanka, double polypropylene bags are used. Mace is usually packed in wooden cases of 60 kg capacity each, but smaller sizes are sometimes shipped.

Nutmeg oil is packed in 180 to 200 kg capacity steel drums (suitably enameled or coated). The nutmeg oleoresin is normally packed in plastic PVC foils of various capacities viz. 15, 20 and 25 kg PVC of which 25 kg is the most popular in the industry. Mace is dull yellowish red, translucent and brittle (Pruthi, 2001).

The nuts are ovoid, approximately 2.25 to 2.75 cm long 1.75 to 2.25 cm diameter and longitudinally wrinkled. The colour is greyish brown with furrows network of dark brown veins, in which volatile oil is found. The dried mace can be packed in air tight containers or polybags which are approved for organic products with protection from sunlight so as to protect the red coloured pigment lycopene which is highly susceptible to oxidation in light.

Spices are hygroscopic and interact with moisture in the atmosphere. The risk of mould growth is natural and therefore it should be protected from relative humidity. The mace can be stored for more than a year in thick plastic barrels with airtight lid and sealed with cellophane tape around the lid. Nutmeg is usually packed in polythene bags of 50 kg capacity. The ideal temperature for storing nutmeg is 20 to 25^{0}C and at higher temperature essential oil may be lost (WSO, 2007).

Spices are hygroscopic goods which interact with the moisture in the air. Nutmeg should be protected from relative humiditities of more than 75 per cent, otherwise mould growth sets in (Jayashree and Chempakalam, 2011).

2.5.2 Effect of packaging materials and storage on microbial quality of spices

According to Silverman and Goldblith (1965) improper packaging and storage conditions may assist microbial survival.

Chang and Kim (1976) found that for long term storage of chilli or chilli powder, aluminium foil laminate was unique in offering maximum protection from various physico-chemical changes. Amber or black polyethylene, high density polyethylene and saran /cellulose/saran polylaminate pouches were found to be suitable alternatives for short term storage and for fairly good moisture and colour protection.

Microflora of fresh-unwashed, fresh-washed, blanched, frozen, dried and aseptically harvested fresh parsley was evaluated by Kaferstein (1979) in a study done in Germany. Geometric means for mesophilic aerobic counts ranged from 5.1 x 10^{3} colonies in fresh blanched parsley to 3.7 x $l0^{7}$ colonies in fresh, unwashed parsley. Geometric means for *Enterobacteriaceae* ranged from 4 x $l0^{2}$ colonies in fresh blanched parsley to 4.7 x 10^{6} colonies in fresh, unwashed parsley.

Based on the systemic studies conducted on the Equilibrium Relative Humidity (ERH), sorption isotherms, packaging in different types of containers and their storage at room temperature for months, Pruthi and Saxena (1984) suggested packaging and storage of dried *Prunica granatum*. L in friction top tins gives good storage life.

The factors causing deterioration in foods are (i) inherent properties of the food which cannot be prevented by packaging and (ii) properties which are dependent on environment and are possible to control by the type of packaging employed (Ranganna, 1986).

Pakkonen *et al*. (1990) conducted a study on drying, packaging, and storage effect on quality of basil, majoram, and wild majoram and reported that odour and taste of freeze dried basil and freeze dried and air dried majoram were sensitive to storage conditions. Intensity of odour and taste of dried herbs could be maintained for two years at 23^0C in air tight packaging.

According to Al-Jassir (1992) many spices are grown and harvested in poor sanitary conditions in areas abundant in warmth and humidity. Such conditions lay the groundwork for potential microbiological contamination. Numerous studies have indicated high microbial loads in spices and herbs which could pose a problem for food manufacturers. A study conducted in Saudi Arabia to evaluate the microflora of black cumin seeds revealed that total aerobic bacteria count was reported to be 7×10^7 cfu/g, whereas *Staphylococcus aureus* and *Bacillus cereus* were detected in low numbers.

The collection and manipulation of spices is not always performed under rigorous hygienic conditions, which can lead to high microbial counts and the consequent damage to the food in which they are used (McKee, 1995).

Studies on the effect of modified atmospheric packaging in chiku by Mohamed *et al*. (1996) have shown that minimum spoilage due to pathogens was seen in the vacuum packed fruits and no pathogenic spoilage was observed at storage temperature of 5ºC.

Achour *et al*. (2003) studied the effect of vacuum and modified atmosphere packaging on the storage of Deglet Nour date and found decreased dehydration during storage under both the conditions. For natural dates stored at less than 20°C, the application of partial vacuum packaging increased shelf life from 3 to 9 months compared to simple sealing.

Spices deteriorate rapidly under adverse conditions and should be stored in well maintained storage facilities. It is essential that the moisture level of the spice to be stored is at a safe level, usually below 10 per cent moisture to ensure storage without mould growth (Doughas *et al*., 2005).

According to Rahman (2007) the water activity is almost same in heat sealable laminated aluminium film throughout the storage period but increased in case of HDPE and PP film. The flavour remained unchanged upto two months in PP and six months in HDPE but quite strong flavour upto 12 months in heat sealable laminated aluminium pouch. Among the three packaging materials, the shelf life of coriander powder is found to be the best in heat sealable laminated aluminium pouch. From this study it was concluded that for long time storage of coriander at ambient conditions, heat sealable laminated aluminium pouch is found to be best.

Gupta *et al.* (2008) observed that contamination of medicinal herbs with aflatoxins after harvesting can be minimized by controlling the water activity and storage temperature, as *Aspergillus flavus* did not grow in any of the samples of medicinal herbs with water activity above 0.81 and when stored below 10±2°C.

No microbiological standards are there for dried spices and herbs in European Community legislation, however, the Codex Code of Hygienic Practice specifies that dried spices and herbs should be free from pathogenic microorganisms at levels that may represent a hazard to health and further requires that *Salmonella* should be absent in treated ready-to eat spices. The European Spice Association (ESA) also specified that *Salmonella* should be absent in 25 g of spice, *Escherichia coli* to be present at less than 10^2 cfu/g (Sospedra *et al.*, 2010).

According to Ariff (2011) ayam percik (roasted spicy chicken) packaged in normal air spoiled after four weeks as indicated by high microbial counts, where as in the CO_2 packages shelf life of ayam percik was extended to seven weeks and it was concluded that the elimination of O_2 from the packages and the introduction of different concentrations of CO_2 and N_2, together with adequate refrigeration, inhibit the growth of aerobic microorganisms, proteolytic bacteria, yeasts and fungi.

The issue of aflatoxin and other impurities in nutmeg and mace had been a point of concern since these contributed to the deterioration of quality. The Rapid Alert System for Food and Feed (RASFF) notifications by the European Union had called for immediate measures to counter the great challenge in enhancing the quality of nutmeg and mace exported devoid of aflatoxin (Thampi, 2011).

2.5.3 Mace oil

Clevenger (1952) reported that yield of oil is about 4 to 17 per cent as a colourless to pale yellow to almost water-white mobile liquid possessing fresh, warm spicy and aromatic odour with a rich sweet spicy body note. The oil partly resinfies and develops a turpentine like odour upon exposure to air.

Dann *et al*. (1977) showed the general composition of the cured mace oils as 75 to 94 per cent monoterpene hydrocarbons, 7 to 17.6 per cent oxygenated monoterpenes and sesquiterpenes and 0.5 to 9 per cent aromatic ether.

The nutmeg oil has been found to be effective in arresting growth of aflatoxin B produced by *Aspergillus parasiticus* by 40 per cent (Tiwari *et al*., 1983).

Lewis (1984) reported that the nutmeg mace and their oils are generally used with sweet foods like cakes, cookies, doughnuts, fruit poise, eggnog and puddings to give them a delicate smooth flavour. The oil is used in canned soups and stews and has an important application in neutralizing the unpleasant smell of cooked cabbage.

Nutmeg oil has aromatic, stimulant, narcotic, carminative, astringent, aphrodisiac, hypolipidemic, antithrombotic, antiplatelet aggregation, antifungal, antidysentric, anti-inflammatory properties (Nadkarni, 1988).

Gopalakrishnan (1992) reported that myristicin is the main organoleptic component in the mace oil. It gives the true aroma and flavour of the spice. In Indian mace myristicin is the main chemical component in the mace.

Hallstorm and Thuvander (1997) reported the toxicological evaluation of myristicin or methoxy safrole, the principal aromatic constituent of nutmeg and mace oil. Ingestion of 5 g nutmeg mace corresponding to 1 to 2 mg myristicin per kg body weight has been shown to cause intoxication.

Mallavarapu and Ramesh (1998) reported that nutmeg oil contained 76.8 per cent monoterpenes, 12.1 per cent oxygenated monoterpenes and 9.8 per cent phenyl propanoid ether. It was also reported that mace oil consists of 51.2 per cent monoterpenes, 12.1 per cent oxygenated monoterpenes, 30.3 per cent oxygenated monoterpenes and 18.8 per cent phenyl propanoid ether. The oleoresin or the solvent extract represents the total pungency and flavour of nutmeg mace.

Alzoreky and Nakahara (2002) reported that essential (volatile) plant oils (EOs) occur in edible, medicinal and herbal plants and have been widely used as flavouring agents in foods since the earliest recorded history. It is well established that many EOs, have anti microbial activity against a wide range of spoilage and pathogenic bacteria.

Significant work on *M. fragrans* essential oil has been carried out in different parts of India and it is observed that chemical composition of nutmeg oil was influenced by location (Evans, 2003).

Nutmeg oil has aromatic, stimulant, narcotic, carminative, astringent, aphrodisiac, hypolipidemic, antithrombotic, antiplatelet aggregation, antifungal, antidysentric, anti-inflammatory properties (Nadkarni, 1988). The presence of myristicin and elemicin in nutmeg is often related to the hallucinogenic action, while, safrole has been suspected to be carcinogenic (Taketa *et al.,* 2004).

Krishnamurthy and Mathew (2006), reported that monoterpene hydrocarbons together with smaller amount of oxygenated monoterpenes and aromatic ethers are the major constituents of both nutmeg and mace oil.

The nutmeg leaves yield 0.41 to 0.60 per cent of light brown volatile oil with a pleasing spicy odour on water distillation. Steam distillation of dried leaves give 1.58 per cent of a colourless volatile oil containing alpha-pinene (80%) and myristicin (10%). Oil of mace resembles nutmeg oil in odor, flavour and composition and no distinction is made between them in the trade. Like nutmeg oil, mace oil also becomes viscous on storage due to absorption of oxygen. Old mace yields more viscous oil than the fresh one (Anon, 2008).

According to Bakkali *et al.* (2008) myristicin (5-allyl-1-methoxy-2,3 methylenodioxy benzene) is the main component of nutmeg (*Myristica fragrans* Houtt.) essential oil which exists in the nut called nutmeg and in mace, the waxy red covering of the nutmeg seed.

The seeds of nutmeg are carminative, diuretic, stomachic, astringent, deodorant, narcotic, aphrodisiac and useful in treatment of flatulence, nausea and vomiting. Oil of nutmeg is useful in the treatment of inflammation of the bladder and urinary tract, halitosis, dyspepsia, flatulence, impotence, insomnia and skin diseases (Krishnamoorthy and Rema, 2011).

The nutmeg plant material was chopped and subjected to hydro distillation for three hours using Clevenger type apparatus to get the nutmeg essential oil and the amount of oil yielded in the samples from North East and Kerala were 8.5 and 7.25 per cent, respectively (Kumar 2012).

2.5.4 Oleoresin

Naves (1974) stated that mace oleoresin is prepared by extracting the comminuted spices with organic solvents and the commercial products exhibit a range in their essential oil and fatty oil contents. The relative proportions of these components are dependent upon the type of extraction solvent used. Oleoresins containing a relatively high fat content, obtained by extraction with non-polar solvents are preferred for use in flavouring processed foods since they have greater tenacity and stability to heat. In contrast, perfumes find oleoresins extracted with more polar solvents, such as ethanol, to be superior being soluble in most perfume materials. Commercial mace oleoresins are available with volatile oil content ranging from 10 to 55 per cent. When extracted with petroleum ether, it yields 27 to 32 per cent and contains 8.5 to 22 per cent volatile oils and after chilling the yield reduces to 10 to 13 per cent.

Purseglove *et al*. (1981) reported that extraction of nutmeg mace with organic solvents provides an oleoresin with exact odour, flavour and pungent principles of the spice. The orgenoleptic properties of the oleoresin were determined by its volatile oil and myristicin content.

According to Omobuwajo *et al.* (2003) the seeds of calabash nutmeg (*Monodora myristica*) seeds contains 7.67 per cent moisture, 3.02 per cent volatile oil (v/w), 21.30 per cent oleoresin.

2.5.5 Sensory quality

Gopalakrishnan (1980) reported that colour plays an important role in deciding the commercial value of mace and it has been established that its scarlet red colour is due to the pigment lycopene.

According to Sagar *et al*. (1999) the highest score for overall acceptability recorded by nitrogen packs were due to the better retention of colour, flavour and texture. It was also observed that nitrogen packed dehydrated ripe mango slices retained the colour and quality during storage under ambient storage conditions.

According to Akubor and Adejo (2000) the sensory scores for cripsness, flavour and taste of plantain chips decreased with prolonged storage. Leatheriness or loss of cripsness on storage was caused by uptake of moisture from the atmosphere.

Tamarind pulp packed under vaccum sealing and stored under refrigerated temperature retained the brown colour up to 330 days of storage. Extended storage life without deterioration in colour and quality was observed when the pulp was packed and stored under refrigeration (Nagalakshmi and Chezhiyan, 2004).

According to Habeeba (2005) fig (*Ficus carica* L.) samples stored in aluminium foil laminated pouches with vacuum retained their colour and microbial safety.

Both nutmeg and mace are strongly aromatic resinous and warm in taste. Mace is generally said to have a finer aroma than nutmeg, but the difference is small. Nutmeg quickly loses its fragrance when ground; therefore, the necessary amount should be grated from a whole nut immediately before usage. Nutmeg and mace are widely used as condiments and in medicine. It is evaluated for its appearance (colour), pungency and its aroma or flavour properties. The aroma is contributed by its essential oil, which consists of a wide variety of chemical constituents viz. myristicin, elemicin and safrole etc. (Pandey, 2010).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation on "Drying and storage studies in nutmeg (*Myristica fragrans* Houtt.) was carried out at the Department of Processing Technology and Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Thrissur, during 2012-2013.

In this study an attempt has been made to develop a suitable drying and storage technique for both mace and nut of nutmeg (*Myristica fragrans* Houtt.)

3.1 SITE AND CLIMATE

The area (Vellanikkara) is located at 10°32' N latitude, 70°10' E longitude and 22.25 m above mean sea level. The area has a tropical monsoon climate.

3.2 EXPERIMENTAL DETAILS

The whole programme was carried out as three experiments, as detailed below:

3.3 STANDARDIZATION OF PRETREATMENTS

3.3.1 Procurement of nutmeg

The nutmeg fruits (both freshly harvested and fallen) were collected in morning hours from Banana Research Station, Kannara, Thrissur.

The outer fleshy pericarp was removed and the whole nut with and without mace were subjected to different pretreatments along with control and subjected to microbial estimation of bacteria, fungi and actinomycetes. Sample size was 25 nutmegs per treatment.

3.3.2 Pretreatments

3.3.2.1 *Treatments*

Control: Initial count

Plate 1. View of a nutmeg tree

T_1: Washing in plain running water for two minutes

T_2: Washing in luke warm water containing 100 ppm chlorine for two minutes

T_3: Washing in luke warm water containing 1000 ppm alum for two minutes

T_4: Blanching in hot water at 75^0C to 80^0C for two minutes

Best pretreatment based on the microbial load, colour and appearance was selected for further drying studies.

3.4 DRYING

Two materials viz. mace alone and nut alone were used for drying studies.

3.4.1 *Drying methods*

3.4.1.1 *Sun drying*

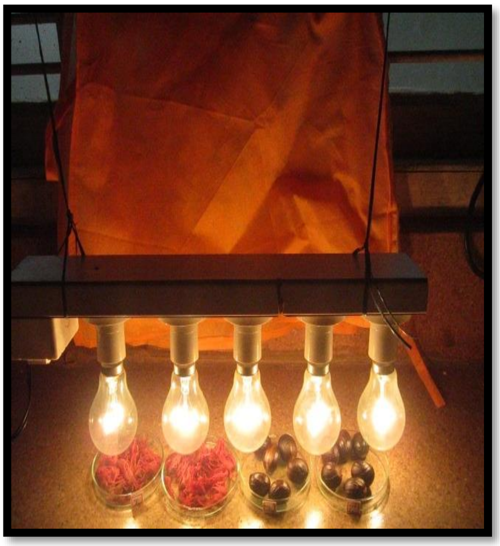
Weighed samples were dried under sun with three replications till a constant weight was obtained. Temperature during drying ranged between 23^0C and 33^0C with an average temperature of 28^0C. Weather parameters prevailed during drying period are given in appendix I.

3.4.1.2 *Country oven drying*

Weighed samples were dried in a country oven drier (coconut drier) till a constant weight was obtained. Temperature during drying ranged between 65^0C and 70^0C.

3.4.1.3 *Mechanical drying*

Mechanical drying of the samples was done using a cabinet drier at 40^0C to 50^0C. A cabinet drier with inner dimensions as 0.9 x 1 x 0.61 m with 2.5 KW heating capacity was used for drying.



Drying under 60 watt burning bulbs

Country oven drying in a copra drier

Sun drying

Mechanical drying in a cabinet drier

Plate 2. Various drying methods employed in the study

3.4.1.4 *Bulb drying*

Weighed samples were dried under close vicinity of 60 watt burning bulbs at a temperature of 72^0C to 76^0C till they attained constant weight for two consecutive readings.

3.4.2 *Layout*

The experiment was laid out in a Completely Randomized Design (CRD) with three replications of 100 g of mace and 200 g of whole nut without mace.

3.4.3 *Observations*

Observations on both physical and chemical changes after drying were taken as detailed below.

3.4.3.1 *Physical observations*

3.4.3.1.1 *Recovery percentage*

Recovery of the dried samples were calculated on initial weight basis as suggested by Srivastava and Tandon (1968) and expressed as percentage.

$$\textit{Recovery percentage} = \frac{\text{Final weight}}{\text{Initial weight}} \times 100$$

3.4.3.1.2 *Residual moisture*

Moisture content was estimated by drying 10 g of the samples in hot air oven at 70 ± 2^0C till the samples attained constant weight. The moisture content was expressed in percentage (Ranganna, 1986).

3.4.3.1.3 *Colour changes*

Change in colour due to different treatments was assessed visually and recorded.

3.4.3.1.4 *Drying rate*

Drying rate was found out for all the treatments using the method described by Narasimham and John (1995). Samples kept for drying were taken at definite intervals and their weight as percentage to original weight was found.

3.4.3.2 *Chemical analysis*

Samples were analysed for oil and oleoresin content.

3.4.3.2.1 *Essential oil*

The volatile oil content of the dried mace was determined by distillation method using Clevenger apparatus as shown in plate 4.

Thirty grams of dried sample and 500 ml of distilled water were taken in a round bottom flask attached to Clevenger apparatus with condenser. The flask was heated with frequent agitation, until distillation commences and the distillation was continued at the rate of 60 to 70 drops per minute. The flask was rotated occasionally to wash down any material adhering to the upper part of the wall. The distillation was carried for three hours and the oil was collected in the receiver of the Clevenger apparatus, which contained distilled water. The extracted oil was cooled to room temperature and allowed to stand until oil layer was clean. The volume of oil collected after cooling was expressed as percent volume (v) per unit mass of sample.

$$\text{Volatile oil (\%)} = \frac{V}{W} \times 100$$

Where, V = Volume of oil collected (ml)

W = Total weight of the sample (g)

3.4.3.2.2 Oleoresin content

The oleoresin was extracted with Petroleum Benzene (40 to 60^{0}C boiling range) by employing a solvent extraction method using a Soxhlet apparatus (Plate 3).

Five grams of powdered sample was packed in a thimble and kept in the extraction tube of the Soxhlet apparatus. About 75 ml of petroleum ether (petroleum benzene) was taken in the Soxhlet flask and attached to the extraction tube along with a condenser. The extraction was continued for three to four hours on a water bath until no colour was observed in the soxhlet apparatus. At the end of the extraction the thimble was removed from the apparatus and distilled further for the removal of the solvent. The traces of the solvent were removed at room temperature by gentle heating.

$$\text{Oleoresin (\%)} = \frac{\text{Weight of extracted oleoresin}}{\text{Initial weight of sample}} \times 100$$

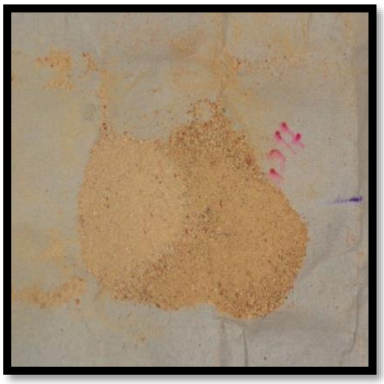
3.5 STORAGE OF DRIED SAMPLES

The nutmeg spice products pretreated with luke warm water containing 1000 ppm alum and dried in a mechanical drier were selected for further storage studies. The experiment was carried out with an objective of finding out a suitable method for storage of dried mace, nut and kernel powder of *Myristica fragrans* Houtt., so as to reduce the quality deterioration, reduce the storage space and also to improve the convenience of its use.

3.5.1 ***Preparation of samples for storage***

Dried mace and nut samples were stored as such and nutmeg kernels were powdered in a grinder. These three forms of materials were filled in six different packaging materials and kept for storage.

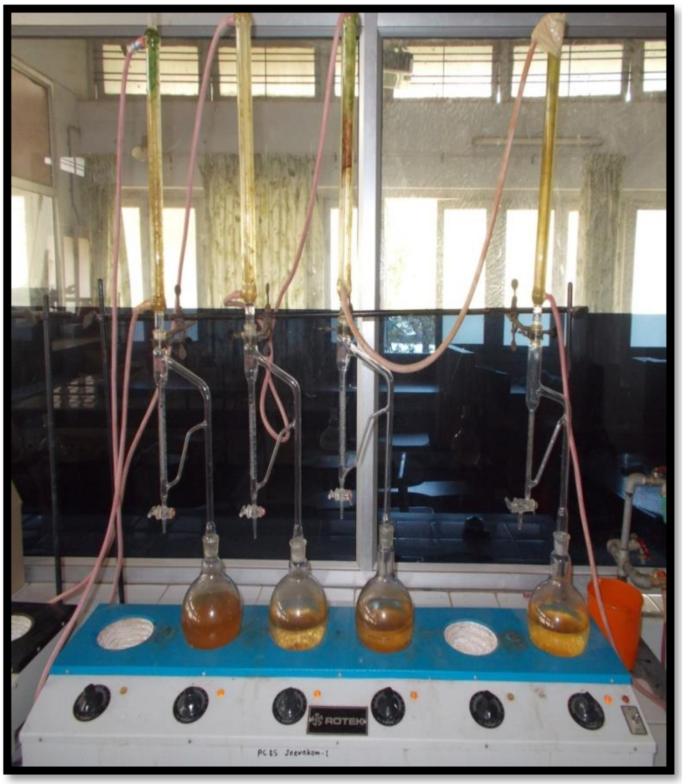
Soxhlet apparatus



Mace before oleoresin extraction **Mace after oleoresin**
extraction

Mace oleoresin

Plate 3. Estimation of oleoresin



Clevenger apparatus

Plate 4. Estimation of oil

3.5.2 *Treatments*

The nutmeg spice products dried in a mechanical drier were stored with different packaging materials (Plate 6).

The nutmeg spice products used are:

1. Whole nut without mace
2. Mace alone
3. Kernel powder (nutmeg kernel was powdered using a mixie)

The experiment was done both with the freshly harvested nutmeg and fallen nutmeg (collected within 24 hours).

T_1: Packaged in 250 gauge polyethylene bags
T_2: Packaged in 250 gauge polythene lined gunny bags
T_3: Packaged in 250 gauge polyethylene bags with nitrogen gas
T_4: Vacuum packaged in 250 gauge polythene bag
T_5: Packaged in aluminium foil laminated pouches
T_6: Packaged in rigid metal containers
Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

3.5.2.1 Gas / vacuum packaging

Materials after preparation were placed in 250 gauge polyethylene bags and placed in a Quick seal vacuum packaging machine (Sevana Electrical Appliances Pvt. Ltd.) three bags at a time. The machine has a chamber capacity of 500 x 400 x 150 mm^3 with sealing heads. For flushing the N_2 gas in to the bags, bags were first evacuated for vacuum and then N_2 gas was flushed into such bags till it attains the requisite gas pressure.

3.5.3 *Layout*

The experiment was laid out in Completely Randomised Design (CRD) with 100 g each.

Plate 5.Various packaging materials used in the study

1. Packaged in 250 gauge polyethylene bags
2. Packaged in 250 gauge polythene lined gunny bags
3. Packaged in 250 gauge polyethylene bags with nitrogen gas
4. Vacuum packaged in 250 gauge polythene bag
5. Packaged in aluminum foil laminated pouches
6. Packaged in rigid metal containers

3.5.4 *Observations*

Observations for physical and chemical parameters, sensory quality and microbial load in the stored samples were taken at trimonthly intervals.

3.5.4.1 *Physical observations*

Physical observations like residual moisture and colour changes of different samples under different packages were determined at trimonthly intervals as stated in 3.4.3.1.2 and 3.4.3.1.3 respectively.

3.5.4.2 *Chemical analyses*

For storage study composite samples were taken at random from the top, middle and bottom of the container or packages as suggested by World Health Organization norms (WHO, 2002) with respect to each treatment for the quantitative estimation of oil and oleoresin content.

3.5.4.3 Quantitative estimation of total microbial population

The quantitative assay of micro flora was carried out by serial dilution and plate count technique (Johnson and Curl, 1972). The sample (20 g each of mace, nut and kernel powder) were added separately to 180 ml sterile distilled water in 250 ml conical flasks and shaken for 30 minutes in an orbital shaker gives 10^{-1} dilution. One millilitre of 10^{-1} sample dilution was transferred to another test tube containing 9 ml sterile distilled water to get 10^{-2} dilution. Later 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} dilutions were prepared from this by serial dilutions.

3.5.4.3.1 *Estimation of fungal population*

One ml of 10^{-3} dilution was pipetted into a sterile Petri dish using a micropipette. About 20 ml of the melted and cooled Potato Dextrose Agar (PDA) media was poured to the Petri dish and it was swirled. After solidification, it was kept for incubation at room temperature. Three Petri dishes were kept as replicate for each sample. The Petri plates were incubated at room temperature for 4 to 5 days. The fungal colonies developed at the end of five days were counted and expressed as cfu/g of the sample.

3.5.4.3.2 ***Estimation of bacterial population***

Bacterial population was estimated using 10^{-6} dilution on Nutrient Agar medium. The method that was used for the estimation of fungal population was followed for estimation of bacterial population. The plates were incubated for 48 hours at room temperature. The bacterial colonies developed were counted and expressed as cfu/g of the sample.

3.5.4.3.3 ***Estimation of actinomycetes population***

The population was estimated using 10^{-5} dilution of the sample. The media used was Kenknight's agar medium and the same method was followed as in the estimation of fungal population. The dishes were incubated at room temperature for 7 to 14 days and the actinomycetes colonies were counted and expressed as cfu/g of the suspension.

Culture media composition for fungi, bacteria and actinomycetes are given in Appendix II.

3.5.4.4 ***Sensory evaluation***

Sensory evaluation was carried out with the help of 14-member semi trained panel on a nine point hedonic scale. Panel members were asked to evaluate mace samples for colour, aroma, appearance and overall acceptability as given in the scorecard. Scorecard used in the evaluation is given in Appendix III.

3.6 TABULATION AND STATISTICAL ANALYSIS

Observations under each experiment were tabulated and analysed statistically in a Completely Randomised Design (CRD) wherever appropriate as proposed by Panse and Sukhatme (1976). The treatments were ranked according to Duncan's Multiple Range Test (DMRT) as suggested by Duncan (1955). Data pertaining to organoleptic evaluation were analysed using Kendall's coefficient of concordance.

RESULTS

4. RESULTS

The results of the studies conducted at the Department of Processing Technology and Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Thrissur during 2012-2013 with the objective of developing suitable pretreatment, drying and storage technique for nutmeg *(Myristica fragrans* Houtt.) grown mainly in Kerala are presented in this chapter under the following titles.

1. Standardization of pretreatment
2. Drying studies
3. Packaging and storage studies

4. 1 STANDARDIZATION OF PRETREAMENT

The peak harvest season of nutmeg falls in the active monsoon. Farmers used to gather nutmeg from the tree as well the fallen nutmeg from the wet ground; as a result the initial microbial load will be heavy and later causes spoilage in storage, therefore an experiment was conducted in order to standardize the pretreatment with an objective to reduce the initial microbial load and the results are presented in tables 4.1 to 4.2b.

4.1.1 *Initial microbial load of nutmeg*

Initial microbial load of both harvested and fallen nutmeg with and without mace was estimated and presented in the table 4.1 (This could be taken as control). The results clearly indicated that significant difference exists between the harvested and fallen nutmeg with or without mace and among them high microbial load ($35x10^6$ cfu/g bacteria, $14x10^3$ cfu/g fungi and $6.0x10^5$ cfu/g actinomycetes) was observed in T_4 (fallen nutmeg without mace) and least microbial load ($5.3x10^6$ cfu/g bacteria, $4.0x10^3$ cfu/g fungi, $1.3x10^5$ cfu/g actinomycetes) was observed in T_2 (harvested nutmeg without mace). The high

Table 4.1. Microbial population of nutmeg before pretreatments

Sample	Total microbial count in cfu/g		
	Bacteria ($\times 10^6$)	**Fungi ($\times 10^3$)**	**Actinomycetes ($\times 10^5$)**
Harvested nutmeg with mace	6.3^{c}	5.3^{bc}	2.6^{c}
Harvested nutmeg without mace	5.3^{c}	4.0^{d}	1.3^{d}
Fallen nutmeg with mace	28.0^{b}	8.6^{b}	4.6^{b}
Fallen nutmeg without mace	35.0^{a}	14^{a}	6.0^{a}

(*Values with different superscript differ significantly*)

The values represent average of three replications microbial load observed in fallen nutmeg could be due to its contact with the wet soil.

4.1.2 *Microbial load after pretreatments*

Microbial load after different pretreatments was evaluated and results are presented in tables 4.2a and 4.2b. No significant difference was observed among the treatments for microbial load in case of harvested nutmeg but in case of fallen nutmeg significant difference was observed among the pretreatments. In either case pretreatment with luke warm water containing 1000 ppm alum was recorded to be the best as it showed least microbial load followed by treatment with luke warm water containing 100 ppm chlorine. Significant reduction in microbial load was observed in the pretreated nutmeg compared to the control. The percentage reduction in the microbial load of pretreated nutmeg (Table 4.2a&4.2b) compared to control (Table 1) was recorded to be the highest in case of nutmeg washed with alum water (70% to 100% reduction in harvested nutmeg and 78% to 96% reduction in fallen nutmeg) and least in case of nutmeg washed with plain running water (25% to 75% reduction in harvested nutmeg and 13% to 70% reduction in fallen nutmeg).

4.1.3 *Changes in colour and appearance due to pretreatments*

No significant difference was observed among the pretreatments with respect to colour and appearance of nutmeg, yet the pretreated nutmeg showed better appearance and colour than the nutmeg without pretreatment in both harvested and fallen nutmeg. Between harvested and fallen nutmeg, harvested nutmeg was superior to fallen nutmeg with respect to colour and appearance as it was free from adherent soil.

Table 4.2a. Microbial population of harvested nutmeg after pretreatments

Treatments (Washing with)	Total microbial count in cfu/g					
	Harvested nut with mace			Harvested nut without mace		
	Bacteria ($x\ 10^6$)	Fungi ($x\ 10^3$)	Actinomycetes ($x10^5$)	Bacteria ($x\ 10^6$)	Fungi ($x\ 10^3$)	Actinomycetes ($x10^5$)
Control	6.3^a	5.3^a	2.6^a	5.3^a	4.0^a	1.3^a
T_1 (Running water)	4.0^b (36.84)	4.0^b (25.00)	1.00^b (62.50)	2.6^b (50.00)	2.6^{ab} (33.33)	0.3^b (75.00)
T_2 (Chlorine water)	2.6^b (57.89)	0.3^c (93.75)	0.3^b (87.5)	1.6^b (68.75)	0.0^c (100.0)	0.0^b (100.00)
T_3 (Alum water)	2.0^b (68.42)	0.0^c (100.0)	0.3^b (87.5)	1.3^b (75.00)	0.0^c (100.0)	0.0^b (100.00)
T_4 (Blanching)	2.6^b (57.89)	3.0^b (43.75)	0.3^b (87.5)	1.6 (68.75)	2.00^b (50.00)	0.3^b (100.00)

(*Values with different superscript differ significantly*)

The values represent average of three replications

[*Values in brackets shows the percentage reduction of microbial load with respect to control*]

Control: Without any pretreatment

T_1: Washing in plain running water

T_2: Washing with luke warm water containing 100 ppm chlorine

T_3: Washing with luke warm water containing 1000 ppm alum

T_4: Blanching in hot water at 75-80^{0}C for two minutes

Table 4.2b. Microbial population of fallen nutmeg after pretreatments

Treatments (Washing with)	Total microbial count in cfu/g					
	Fallen nut with mace			Fallen nut without mace		
	Bacteria ($x 10^6$)	Fungi ($x 10^3$)	Actinomycetes ($x10^5$)	Bacteria ($x 10^6$)	Fungi ($x 10^3$)	Actinomycetes ($x10^5$)
Control	28.0^a	8.6^a	4.6^a	35.0^a	14^a	6.0^a
T_1 (Running water)	9.6^b (65.47)	8.0^a (12.82)	2.0^b (57.14)	10.5^b (69.52)	11.3^{ba} (21.42)	3.0^b (50.00)
T_2 (Chlorine water)	5.0^c (82.14)	0.3^c (96.15)	1.0^b (85.71)	5.6^c (83.80)	1.3^c (90.47)	1.0^c (83.33)
T_3 (Alum water)	4.0^c (85.71)	0.3^c (96.15)	1.0^b (85.71)	4.0^c (88.57)	1.3^c (90.47)	1.3^{bc} (77.77)
T_4 (Blanching)	6.3^c (77.38)	4.3^b (50.00)	1.3^b (78.57)	8.0^{bc} (77.14)	5.6^b (59.52)	2.3^{bc} (61.11)

(*Values with different superscript differ significantly*)

The values represent average of three replications

[*Values in brackets shows the percentage reduction in microbial load with respect to control*]

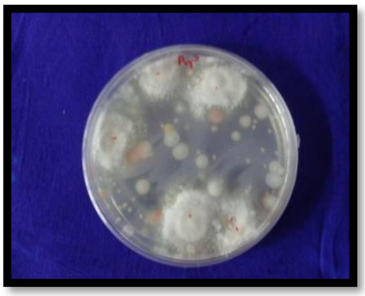
Control: Without any pretreatment

T_1: Washing in plain running water

T_2: Washing with luke warm water containing 100 ppm chlorine

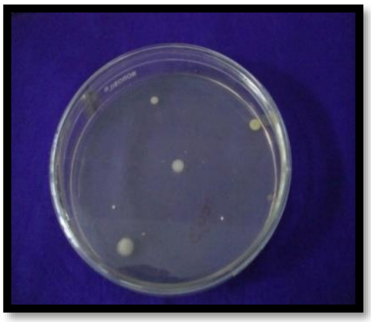
T_3: Washing with luke warm water containing 1000 ppm alum

T_4: Blanching in hot water at 75-80^{0}C for two minutes



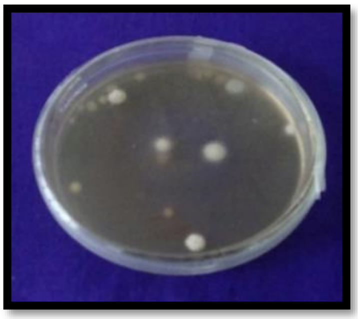
Actinomycetes

Plate 6. Microbial population observed in the nutmeg sample before pretreatment



Bacteria

Fungi



Actinomycetes

Plate. 7. Microbial population observed in the nutmeg sample after washing with 1000 ppm alum water

4.2 DRYING STUDIES

The drying experiment was conducted with an objective of developing an ideal drying method for nutmeg. Drying rates of different drying methods, recovery percentage, residual moisture percentage, oil and oleoresin content, microbial population and sensory evaluation were conducted. These observations were recorded for both harvested and fallen nutmeg and the results are presented in the tables 4.3 to 4.8b.

4.2.1 Recovery percentage, residual moisture and colour change due to drying

Samples were dried to a constant weight and recovery percentage, residual moisture, and colour changes due to drying are recorded and presented here.

4.2.1.1 *Recovery percentage*

Both mace and nut were dried under four methods of drying viz. sun drying, country oven drying, bulb drying and mechanical drying. Significant difference was observed among the drying methods and highest recovery percentage (48.50% and 69.56% for mace and nut respectively in harvested nutmeg; and 48.60% and 70.16% for mace and nut respectively in fallen nutmeg) was recorded in T_1 (sun dried samples) followed by T_2 (oven dried samples) and least recovery percentage was recorded in (T_3) i.e. bulb dried samples of mace (43.98% and 44.16% for harvested and fallen nutmeg mace respectively) whereas in case of nut least recovery percentage (63.66% for harvested nut and 65.26% for fallen nut) was recorded in T_4 (mechanically dried samples). However fallen nutmeg showed slightly higher recovery percentage than harvested nutmeg in all the drying methods (Table 4.3).

4.2.1.2 *Residual moisture*

The amount of residual moisture in percentage retained in each samples of both harvested and fallen nutmeg was analysed. It was observed that lowest value (6.80% and 6.88% in harvested and fallen nutmeg mace respectively) was in the case of T_3, when mace was dried under 60 watt burning bulbs. In case of harvested nut, lowest value (6.90%) was in T_4, when the nut was dried in a mechanical drier whereas in fallen nut lowest value (6.88%) was in T_3, when dried under close vicinity of 60 watt burning bulbs (Table 4.3). Highest residual moisture percentage was recorded in the case of T_1 (sun dried) for all the samples owing to low temperatures, prevailed during drying (temperature ranged between 23.9^{0}C and 30.1^{0}C).

4.2.1.3 *Colour changes due to drying*

Colour is one of the important attributes of any dried material. During drying, the initial scarlet red colour of mace was changed to light red to reddish brown colour. Visual assessments of the colour of dried materials were carried out. It was observed that mace dried in a mechanical drier showed better colour than other methods of drying. In case of drying under 60 watt burning bulbs slight bleaching of colour was observed owing to its high temperature of 72 to 76^{0}C during drying, whereas oven dried mace showed dark brown colour.

4.2.2 *Drying rate*

Rate of drying of nutmeg under different methods were analysed. Rate of drying will depend on several factors like temperature and relative humidity around the drying material, surface area and the nature of the material. Rate of drying for different drying methods were plotted as drying rate curves and are presented in tables 4.4a to 4.5b and fig 1 to 5.

Plate 8. Harvested nutmeg mace dried under different methods

1. Sun dried mace
2. Bulb dried mace
3. Country oven dried mace
4. Mechanically dried mace

Table 4.3. Effect of drying methods on recovery and residual moisture percentage of dried nutmeg

Treatments	Harvested nutmeg				Fallen nutmeg			
	Recovery (%)		Residual moisture (%)		Recovery (%)		Residual moisture (%)	
	Mace	Nut	Mace	Nut	Mace	Nut	Mace	Nut
T_1	48.50^a	69.56^a	9.63^a	10.23^a	48.60^a	70.16^a	10.03^a	10.43^a
T_2	45.44^b	65.40^b	7.56^b	5.91^b	45.66^b	66.43^b	7.73^b	5.32^c
T_3	43.98^c	64.00^c	6.80^c	5.39^c	44.16^d	65.46^c	6.88^c	5.56^{bc}
T_4	44.77^{bc}	63.66^c	6.90^c	5.11^c	44.93^c	65.26^c	7.06^c	5.63^b
Control	45.36^b	64.35^c	7.46^b	5.35^c	45.72^b	66.50^b	7.56^b	5.53^{bc}

(*Values with different superscript differ significantly*)

The values represent average of three replications

T_1: Sun drying

T_2: Oven drying

T_3**:** Bulb drying

T_4: Mechanical drying

Control: Nutmeg without pretreatment but mechanically dried

In the four methods of drying, drying of mace under close vicinity of 60 watt burning bulbs was observed to be faster compared to other methods of drying and slow drying rate was observed in sun drying. The trend was followed both in harvested nutmeg mace and fallen nutmeg mace (Fig. 1-5).

Sun drying of mace took 16 hours for attaining constant weight, whereas other methods took only seven hours for attaining constant weight. Among all the methods, mechanical drying of mace resulted in uniform colour.

In case of drying nut, the least time taken for drying was in oven drying (14 hours) followed by mechanical drying and bulb drying (18 hours each). Longest drying time was recorded in sun drying 56 hours (8 days X 7 hours per day). The trend was followed both in harvested nutmeg as well in fallen nutmeg.

4.2.3 *Microbial population of nutmeg dried under different drying methods*

Microbial population in the dried samples after drying was estimated and presented in table 4.6. Results showed that microbial population was less in harvested nutmeg whereas fallen nutmeg showed slightly higher microbial population than harvested nutmeg. The actinomycetes population was recorded to be almost zero in harvested samples whereas slight growth was observed in fallen nutmeg.

When drying methods were compared for microbial population, least microbial growth was observed in bulb dried and mechanically dried samples than other methods. The control samples (nutmeg without pretreatment but mechanically dried) showed maximum microbial population ($1.6x10^6$ cfu/g bacteria, $1.6x10^3$ cfu/g fungi and $0.6x10^5$ cfu/g actinomycetes in harvested nutmeg mace; $4.6x10^6$ cfu/g bacteria, $3.3x10^3$ cfu/g fungi and $1.6x10^5$ cfu/g actinomycetes in fallen nutmeg mace); followed by sun dried samples (T_1), whereas least microbial population was noticed in mechanically dried samples

Table 4.4a. Drying rate of nutmeg mace dried under different drying methods

Duration (Hours)	Percentage weight to original weight					
	Harvested nutmeg mace			Fallen nutmeg mace		
	OD	MD	BD	OD	MD	BD
0	100	100	100	100	100	100
1	88.32	86.27	82.43	90.54	88.46	85.60
2	71.53	74.16	70.15	73.35	75.40	72.35
3	62.41	64.50	62.06	63.64	66.30	64.26
4	55.47	56.13	54.96	57.67	59.13	56.96
5	47.91	48.85	46.12	50.20	52.00	48.62
6	45.83	46.16	44.24	48.00	48.56	46.45
7	44.12	45.23	43.35	46.30	47.40	45.50
8	44.12	45.23	43.35	46.30	47.40	45.50

The values represent average of three replications

OD: Oven drying

MD: Mechanical drying

BD: Bulb drying

Table 4.4b. Drying rate of nutmeg mace dried under sun

Duration (Hours)	Percentage weight to original weight	
	Harvested nutmeg mace	Fallen nutmeg mace
0	100	100
2	90.08	92.28
4	81.65	83.50
6	72.41	74.54
8	65.42	67.50
10	58.56	60.66
12	52.48	54.70
14	48.89	50.40
16	48.20	50.90

The values represent average of three replications

DRYING CURVES

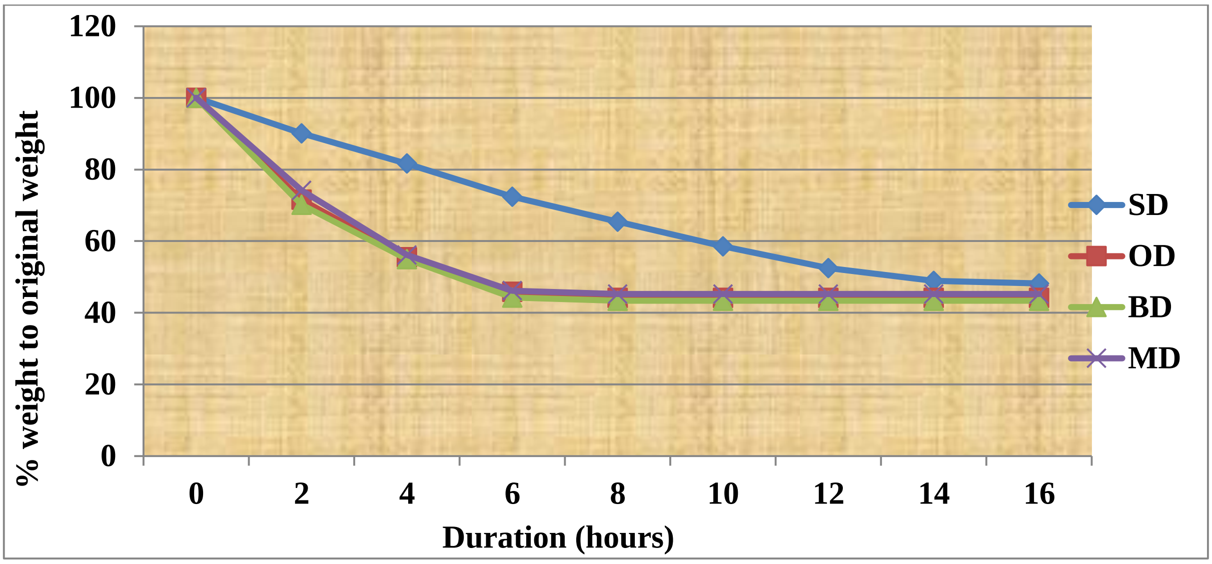


Fig: 1. Drying curve of harvested nutmeg mace dried under different methods

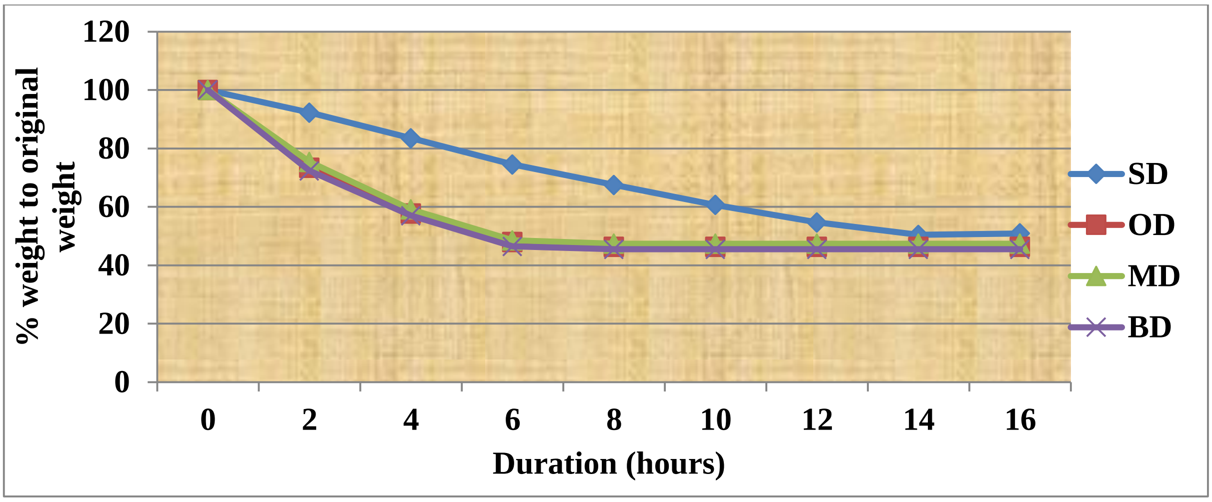


Fig: 2. Drying curve of fallen nutmeg mace dried under different methods

SD: Sun drying

OD: Oven drying

MD: Mechanical drying

BD: Bulb drying

Table 4.5a. Drying rate of nutmeg nut dried under different drying methods

Duration (Hours)	Percentage weight to original weight					
	Harvested nut			Fallen nut		
	OD	MD	BD	OD	MD	BD
0	100.00	100.00	100.00	100.00	100.00	100.00
2	87.23	95.07	87.66	86.00	94.07	89.66
4	80.79	90.30	81.83	82.60	89.30	83.83
6	75.30	86.30	76.30	78.80	85.30	78.30
8	71.42	81.50	72.07	75.26	81.50	74.07
10	68.34	77.30	70.16	72.40	75.40	71.40
12	66.00	73.80	68.95	69.20	72.10	69.30
14	64.21	70.40	67.09	67.30	69.650	68.40
16	64.21	67.50	66.35	65.71	68.20	67.10
18	64.21	65.10	64.30	65.71	66.32	65.80
20	64.21	65.10	64.30	65.71	66.32	65.80

The values represent average of three replications

Table 4.5b. Drying rate of nutmeg nut dried under sun

Duration (Days)	Percentage weight to original weight	
	Harvested nut	Fallen nut
0	100	100
1	88.86	90.86
2	80.95	82.95
3	76.54	77.54
4	73.93	74.93
5	72.38	73.38
6	71.00	72.00
7	69.80	71.10
8	69.80	70.20
9	69.80	70.20

The values represent average of three replications
OD: Oven drying

MD: Mechanical drying

BD: Bulb drying

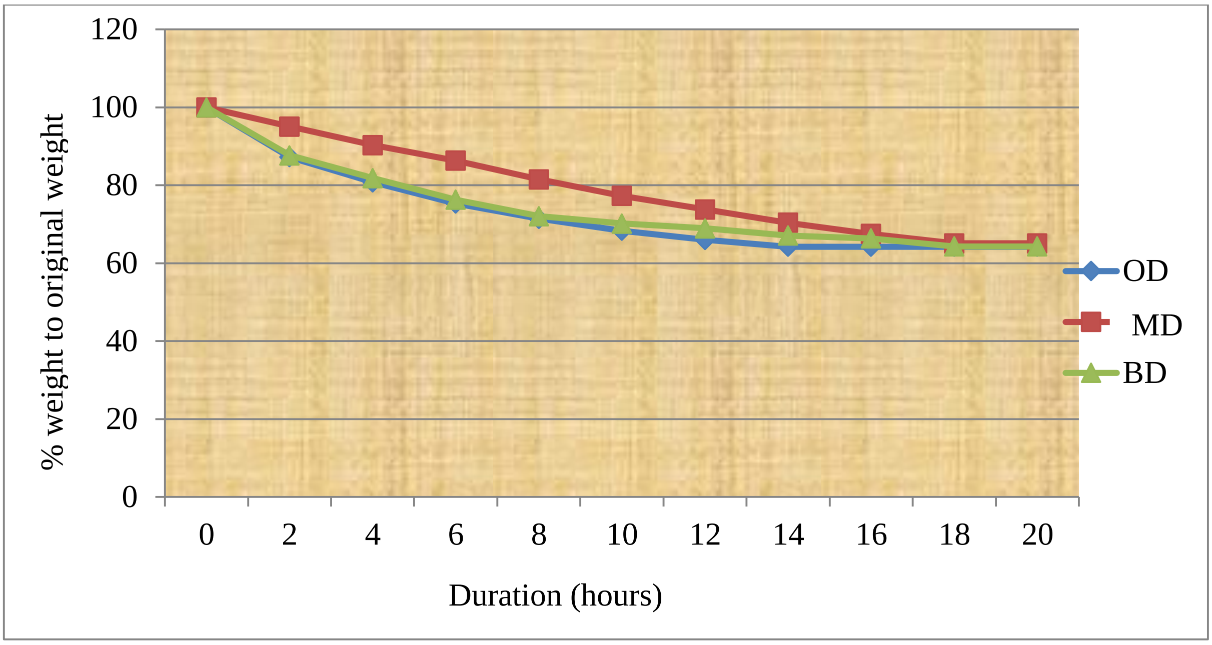


Fig: 3. Drying curve of harvested nutmeg nut dried under different methods

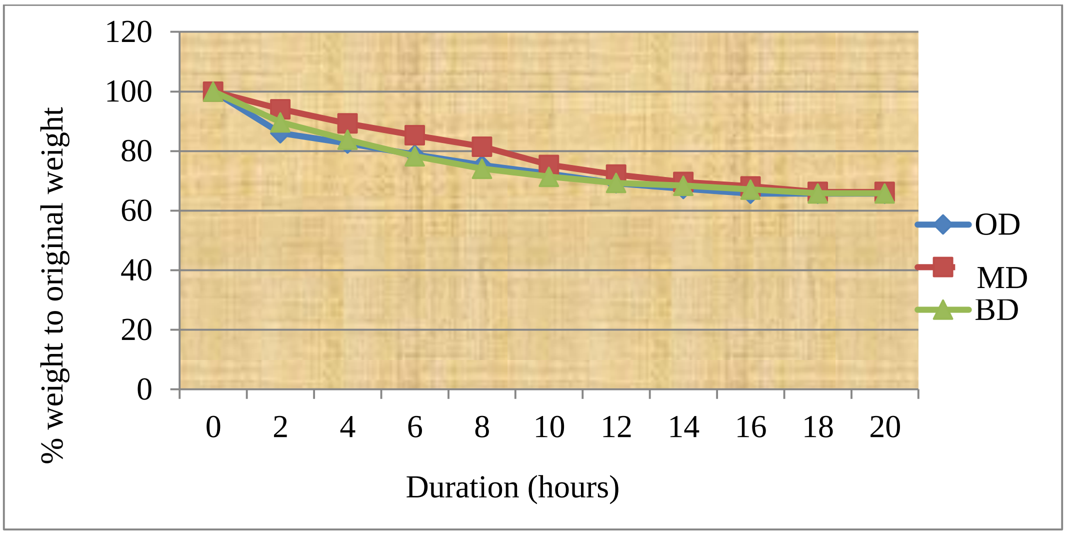


Fig: 4. Drying curve of fallen nutmeg nut dried under different methods

OD: Oven drying

MD: Mechanical drying

BD: Bulb drying

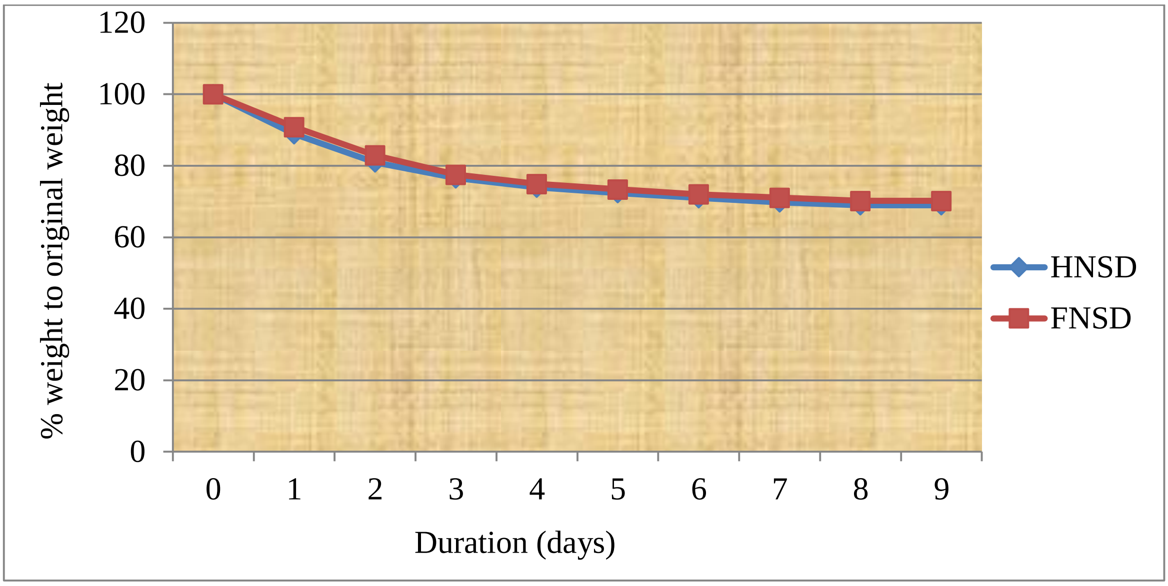


Fig: 5. Drying curve of nutmeg nut dried under sun

HNSD: Harvested nut sun dried

FNSD: Fallen nut sun dried

($0.3x10^6$ cfu/g bacteria, $0.6x10^3$ cfu/g fungi and zero actinomycetes in harvested nutmeg mace; $1.3x10^6$ cfu/g bacteria, $1.6x10^3$ cfu/g fungi and $0.3x10^5$ cfu/g actinomycetes in fallen nutmeg mace). High microbial population in control (nutmeg without pretreatment but mechanically dried) was probably due to high initial microbial load. This clearly explains the importance of pretreatment in reducing the initial microbial load of nutmeg.

Similar results were observed in nut also (Table 4.8) but in case of fallen nut higher microbial population was observed in sun dried nut than control (nutmeg without pretreatment but mechanically dried).

4.2.4 *Oleoresin and oil content of nutmeg dried under different drying methods*

Oleoresin and oil are the two important products from nutmeg. Both harvested and fallen nutmeg dried under different methods were analysed for oil and oleoresin content and the results are presented in table 4.7.

When drying methods were compared for oil and oleoresin content of harvested nutmeg, it was recorded that nutmeg dried in a mechanical drier (T_4) yielded higher oil content 8.4 per cent and 8.06 per cent in mace and nut respectively followed by control 8.25 per cent and 7.96 per cent in mace and nut respectively and least quantity of oil was recorded in sun dried nutmeg mace (T_1) 7.28 per cent and oven dried nut 7.34 per cent. Similarly higher oleoresin content was observed in mechanically dried nutmeg (T_4) 22.40 per cent and 29.09 per cent in mace and nut respectively followed by control 21.06 per cent and 28.26 per cent in mace and nut respectively and least oleoresin content was observed in bulb dried mace (T_3)19.40 per cent and sun dried nut (T_1) 26.95 per cent. Similar results were observed in fallen nutmeg also. On comparison of harvested nutmeg with fallen nutmeg, harvested nutmeg showed slightly higher oil and oleoresin content than fallen nutmeg.

Table 4.6. Microbial population of nutmeg dried under different drying methods

Treatments	Total microbial count in cfu/g					
	Mace			Nut		
	Harvested nutmeg					
	Bacteria (x 10^6)	Fungi (x 10^3)	Actinomycetes (x 10^5)	Bacteria (x 10^6)	Fungi (x 10^3)	Actinomycetes (x 10^5)
T_1	3.3^a	1.3^a	0.3^a	1.6^a	1.3^a	0.33^a
T_2	1.6^b	1.3^a	0.0^a	1.6^a	0.6^a	0.0^a
T_3	0.6^{bc}	0.6^a	0.0^a	0.6^a	1.3^a	0.0^a
T_4	0.3^c	0.6^a	0.0^a	0.6^a	0.6^a	0.0^a
Control	1.6^b	1.6^a	0.6^a	1.3^a	1.6^a	0.6^a
	Fallen nutmeg					
T_1	4.0^b	3.0^{ab}	0.6^{ab}	3.3^a	4.3^a	1.0^b
T_2	2.3^c	1.6^{bc}	0.6^{ab}	2.3^{ab}	2.3^b	0.0^b
T_3	2.0^c	1.3^c	0.6^{ab}	2.0^b	2.6^b	0.3^b
T_4	1.3^c	1.6^{bc}	0.3^b	1.6^b	1.6^b	0.0^b
Control	4.6^a	3.3^a	1.6^a	2.3^a	2.3^b	2.3^a

(*Values with different superscript differ significantly*)
The values represent average of three replications

T_1: Sun drying

T_2: Oven drying

T_3**:** Bulb drying

T_4: Mechanical drying

Control: Nutmeg without pretreatment but mechanically dried

Table 4.7. Effect of drying methods on oil and oleoresin content of nutmeg

Treatments	Oil content % (v/w)				Oleoresin (%)			
	Harvested nutmeg		Fallen nutmeg		Harvested nutmeg		Fallen nutmeg	
	Mace	Nut	Mace	Nut	Mace	Nut	Mace	Nut
T_1	7.28^{c}	7.93^{a}	7.26^{c}	7.96^{a}	20.13^{bc}	26.95^{c}	19.73^{b}	25.26^{c}
T_2	7.89^{b}	7.34^{b}	7.81^{b}	7.38^{c}	20.43^{b}	27.80^{bc}	19.83^{b}	27.12^{b}
T_3	7.95^{b}	7.83^{a}	7.85^{b}	7.58^{c}	19.40^{c}	27.10^{c}	19.40^{b}	26.63^{bc}
T_4	8.40^{a}	8.06^{a}	8.25^{a}	8.10^{a}	22.40^{a}	29.09^{a}	22.00^{a}	28.90^{a}
Control	8.25^{a}	7.96^{a}	8.06^{a}	7.86^{b}	21.06^{b}	28.26^{ab}	20.46^{b}	27.56^{ab}

(*Values with different superscript differ significantly*)

The values represent average of three replications

T_1: Sun drying

T_2: Oven drying

T_3**:** Bulb drying

T_4: Mechanical drying

Control: Nutmeg without pretreatment but mechanically dried

4.2.5 ***Sensory evaluation***

The sensory evaluation was carried out on a nine point hedonic scale using score card for four attributes namely colour, aroma, appearance and overall acceptability. Each character was scored on the scale and the total scores calculated out of thirty six.

Harvested and fallen nutmeg mace dried through different drying methods was used for sensory evaluation and in case of harvested nutmeg mace highest total sensory score (32.8) was recorded in T_4 (mechanically dried) followed by (30.2) in control and least (25.3) in T_1 (sun dried). Highest mean rank for overall acceptability (4.10) was in T_4 (mechanically dried) and least (1.25) in T_1 (sun dried) and higher the mean rank better is the quality. Kendall’s coefficients of concordance among the judges on all the characteristics were highly significant (Table 4.8a).

In case of fallen nutmeg mace highest total sensory score (28.8) was recorded in T_4 (mechanically dried) followed by (26.3) in T_2 (oven dried) and least (23.0) in control. Highest mean rank for overall acceptability (4.20) was recorded in T_4 (mechanically dried) and least (1.75) in T_1 (sun dried). Kendall’s coefficients of concordance among the judges on all the characteristics were highly significant (Table 4.8b).

From the results of Exp. 4.2 it was concluded that alum pretreated and mechanically dried nutmeg was found to be the best material and hence selected for further storage studies.

Table 4.8a. Sensory evaluation of harvested nutmeg mace dried under different drying methods

Treatments	Colour	Aroma	Appearance	Overall acceptability	Total score
T_1	6.7 (2.0)	7.3 (2.70)	5.6 (1.45)	5.7 (1.25)	25.3
T_2	7.6 (3.1)	7.5 (3.00)	6.3 (1.90)	7.5 (3.45)	28.9
T_3	6.8 (2.35)	6.8 (2.15)	7.7 (3.70)	7.3 (3.05)	28.6
T_4	8.5 (4.55)	8.1 (4.05)	8.1 (4.25)	8.1 (4.10)	32.8
Control	7.4 (3.0)	7.6 (3.10)	7.7 (3.70)	7.5 (3.45)	30.2
Kendall's coefficint	0.446*	0.235*	0.695*	0.514*	

(*Values in the parenthesis represent mean rank*)

Values represent average of 14 judges

* Significant

Table 4.8b. Sensory evaluation of fallen nutmeg mace dried under different drying methods

Treatments	Colour	Aroma	Appearance	Overall acceptability	Total score
T_1	6.0 (2.35)	7.0 (2.55)	5.2 (2.20)	4.8 (1.75)	23.0
T_2	6.5 (3.20)	7.3 (3.20)	5.8 (2.85)	6.7 (3.55)	26.3
T_3	6.0 (2.50)	6.8 (2.35)	6.5 (4.00)	6.6 (3.65)	25.9
T_4	7.4 (4.55)	7.5 (3.65)	6.8 (4.30)	7.1 (4.20)	28.8
Control	5.9 (2.40)	7.3 (3.25)	4.9 (1.65)	5.2 (1.85)	23.3
Kendall's coefficint	0.443*	0.156*	0.595*	0.574*	

(*Values in the parenthesis represent mean rank*)

Values represent average of 14 judges

* Significant

T_1: Sun drying

T_2: Oven drying

T_3**:** Bulb drying

T_4: Mechanical drying

Control: Nutmeg without pretreatment but mechanically dried

4.3 PACKAGING AND STORAGE STUDIES

Both harvested and fallen nutmegs washed with 1000 ppm alum water followed by mechanical drying were employed in the packaging and storage studies along with the control (nutmeg without pretreatment but mechanically dried). Pretreated nutmeg products viz, mace, nut and kernel powder were packaged in four types of packaging materials viz, 250 gauge polyethylene bags, polyethylene lined gunny bags, aluminium laminated pouches and rigid metal containers. In case of polyethylene bags three packaging methods were employed viz, nitrogen packaging, vacuum packaging and air packaging. The control samples were packed in 250 gauge polyethylene bags. All the packed samples were stored under room conditions for a period of six months.

Residual moisture, changes in colour, oil and oleoresin content, sensory evaluation and microbial population of stored samples were taken at trimonthly intervals and presented hereunder.

4.3.1 *Residual moisture*

Moisture is the foremost factor that influences the storage quality of any dried product. Higher amounts of moisture increases the water activity and promote microbial growth and thus quality deterioration of the product takes place.

An increase in the percentage of residual moisture was observed with the advancement of storage. Among the packaging materials aluminium foil laminated pouches showed least ingress of moisture followed by vacuum packs and highest moisture ingress was observed in the samples stored in gunny bag.

In harvested nutmeg least moisture ingress was observed for all the products packaged in aluminium laminated pouches (0.55%, 0.49% and 0.43% increase in residual moisture (RM) for mace, nut and kernel powder respectively after six months of storage) followed by vacuum packaging and high moisture ingress was observed in gunny bag (4.96%, 2.82% and 4.05% increase in RM for mace, nut and kernel powder respectively after six months of storage).

In fallen nutmeg also the spice products packed in aluminium laminated pouches showed least moisture ingress (0.39%, 0.38% and 0.41% increase in RM after six months of storage for mace, nut and kernel powder respectively) whereas gunny bag packed products recorded a hike of 4.89%, 3.04% and 4.22% in RM for mace, nut and kernel powder respectively after six months of storage (Table 4.9).

4.3.2 Colour change

Loss of colour of materials during storage will affect its quality. Colour changes of the stored samples of nutmeg were assessed visually. Aluminium foil laminated pouches showed better colour retention even after six months of storage followed by metal container and least in gunny bag. The mace packed in gunny bag showed colour deterioration even after three months of storage. Vacuum packaging resulted in crushing of mace.

4.3.3 Oil and oleoresin content

The packaging material which retains oil and oleoresin with minimum loss is regarded to be the best packaging material for storage. It was observed that oil and oleoresin content in nutmeg was gradually decreased during storage irrespective of packaging materials but aluminium laminated pouches showed least decrease in oil and oleoresin content and highest oil and oleoresin loss was recorded in gunny bags after six months of storage.

4.3.3.1 Changes in oil content of nutmeg during storage in different packaging materials

Initial oil content of harvested nutmeg was 8.41 per cent in mace and 8.06 per cent in nut and kernel powder. A gradual decrease in the oil content of all

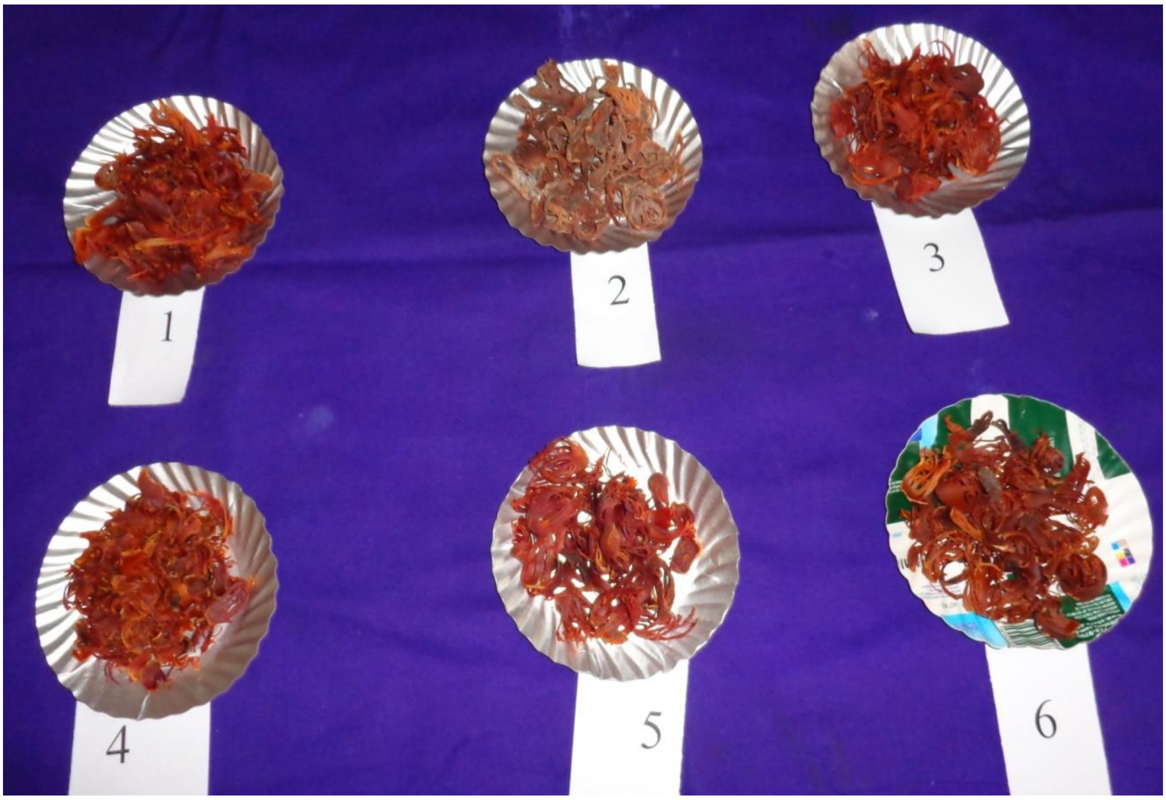


Plate 9. Mace after six months of storage in different packaging materials

1. Mace stored in 250 gauge polyethylene bags

2. Mace stored in 250 gauge polythene lined gunny bags

3. Mace stored in 250 gauge polyethylene bags with nitrogen gas

4. Mace stored in vacuum pack

5. Mace stored in in aluminum foil laminated pouches

6. Mace stored in in rigid metal containers

Table 4.9. Effect of packaging materials on residual moisture percentage of nutmeg during storage

Treatments	Harvested nutmeg								
	Mace			Nut			Kernel powder		
	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS
T_1	7.56^{a}	10.08^{b}	11.29^{b}	5.54^{a}	7.73^{b}	8.03^{b}	6.18^{a}	7.91^{b}	8.50^{b}
T_2	7.56^{a}	10.75^{a}	12.52^{a}	5.54^{a}	8.36^{a}	8.89^{a}	6.18^{a}	9.16^{a}	10.23^{a}
T_3	7.56^{a}	9.57^{c}	10.86^{c}	5.54^{a}	7.40^{c}	7.89^{bc}	6.18^{a}	7.66^{c}	8.25^{c}
T_4	7.56^{a}	9.71^{e}	10.72^{c}	5.54^{a}	6.69^{e}	7.51^{c}	6.18^{a}	7.53^{c}	8.08^{d}
T_5	7.56^{a}	7.93^{d}	8.11^{d}	5.54^{a}	5.86^{f}	6.03^{d}	6.18^{a}	6.43^{d}	6.61^{e}
T_6	7.56^{a}	9.51^{c}	10.73^{c}	5.54^{a}	7.07^{d}	7.61^{c}	6.18^{a}	7.70^{b}	8.26^{c}
Control	7.46^{a}	9.63^{c}	10.23^{c}	5.45^{a}	7.40^{c}	7.77^{bc}	6.08^{a}	7.88^{b}	8.40^{bc}
	Fallen nutmeg								
T_1	7.73^{a}	10.17^{b}	11.50^{c}	5.91^{a}	7.83^{b}	8.13^{b}	6.26^{a}	8.06^{b}	8.70^{b}
T_2	7.73^{a}	10.85^{a}	13.87^{a}	5.91^{a}	8.46^{a}	8.95^{a}	6.26^{a}	9.23^{a}	10.48^{a}
T_3	7.73^{a}	9.51^{c}	10.44^{d}	5.91^{a}	7.50^{c}	8.00^{bc}	6.26^{a}	7.80^{c}	8.33^{c}
T_4	7.73^{a}	9.67^{c}	10.26^{de}	5.91^{a}	6.80^{e}	7.66^{cd}	6.26^{a}	7.53^{de}	8.20^{d}
T_5	7.73^{a}	7.94^{d}	9.79^{e}	5.91^{a}	6.13^{f}	6.29^{d}	6.26^{a}	6.46^{e}	6.67^{e}
T_6	7.73^{a}	9.56^{c}	12.25^{b}	5.91^{a}	7.17^{d}	7.74^{cd}	6.26^{a}	7.73^{cd}	8.35^{c}
Control	7.56^{a}	9.83^{c}	11.91^{b}	5.42^{a}	7.52^{c}	7.93^{bc}	6.20^{a}	8.05^{b}	8.60^{b}

(*Values with different superscript differ significantly*) **MAS**: Months after storage

The values represent average of three replications

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

samples was observed during storage, irrespective of packaging material and after six months of storage, maximum retention of oil content (5.93% in mace, 4.47% in nut and 3.95% in kernel powder) was observed in T_5 (aluminium laminated pouches) and least retention of oil content (3.20% in mace, 2.38% in nut and 0.71% in kernel powder) was observed in T_2 (gunny bags).

In case of fallen nutmeg also, maximum oil content (5.78% in mace, 4.62% in nut and 4.06% in kernel powder) was observed in aluminium laminated pouches and least oil content (3.14% in mace, 2.36% in nut and 0.77% in kernel powder) was observed in gunny bags after six months of storage from an initial oil content of 8.21 per cent in mace and 8.13 per cent in nut and kernel powder. (Table 4.10a and 4.10b).

4.3.3.2 Changes in oleoresin content of nutmeg during storage in different packaging materials

Initial oleoresin content of harvested nutmeg was 22.40 per cent in mace and 29.09 per cent in nut and kernel powder whereas in fallen nutmeg it was 22.06 per cent in mace and 29.63 per cent in nut and kernel powder. During storage, oleoresin content was also decreased but not as drastic as oil. Among mace, nut and kernel powder, oleoresin content was decreased very much in mace and least in nut.

When packaging materials were compared for oleoresin content in harvested nutmeg, it was observed that T_5 (aluminium laminated pouches) retained maximum oleoresin content (17.31% in mace, 26.27% in nut and 25.47% in kernel powder) even after six months of storage. Samples stored in T_2 (gunny bags) showed least retention of oleoresin content (11.78% in mace, 24.08% in nut and 20.76% in kernel powder) after six months of storage. Similar results were observed in fallen nutmeg also (Table 4.11a and 4.11b). Among mace, nut and kernel powder decrease in oleoresin content was less in nut compared to mace and kernel powder.

Table 4.10a. Effect of packaging materials on oil content of harvested nutmeg during storage

Treatments	Oil content % (v/w)								
	Mace			Nut			Kernel powder		
	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS
T_1	8.41^a	6.37^b (24.25)	5.46^b (35.07)	8.06^a	5.26^c (34.73)	4.19^{ab}(48.01)	8.06^a	4.76^b (40.94)	3.51^b (56.45)
T_2	8.41^a	4.53^e (46.13)	3.20^f (61.95)	8.06^a	4.42^e (45.16)	2.38^c (70.47)	8.06^a	1.87^f (76.79)	0.71^e (91.19)
T_3	8.41^a	4.96^d (29.13)	4.21^d (49.94)	8.06^a	5.70^b (29.28)	4.38^b (45.65)	8.06^a	4.18^d (48.13)	3.27^c (59.42)
T_4	8.41^a	6.83^a (18.78)	5.70^{ab}(32.22)	8.06^a	4.80^d (40.44)	4.04^{ab}(49.87)	8.06^a	4.63^b (42.55)	3.30^c (59.05)
T_5	8.41^a	7.02^a (16.52)	5.93^a (29.48)	8.06^a	6.12^a (24.06)	4.47^a (44.54)	8.06^a	5.11^a (36.60)	3.95^a (50.99)
T_6	8.41^a	5.96^c (29.13)	3.80^e (54.81)	8.06^a	6.02^a (25.31)	4.20^{ab}(47.89)	8.06^a	3.12^e (61.29)	1.75^d (78.28)
Control	8.11^b	6.20^{bc}(23.55)	5.18^c (36.12)	7.84^b	5.18^c (33.92)	3.88^b (50.51)	7.84^b	4.50^c (42.60)	3.33^c (57.52)

(*Values with different superscript differ significantly*) **MAS**: Months after storage

The values represent average of three replications

Values in brackets shows the percentage loss of oil content with respect to initial

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried packaged in 250 gauge polyethylene bags

Table 4.10b. Effect of packaging materials on oil content of fallen nutmeg during storage

Treatments	Oil content % (v/w)								
	Mace			Nut			Kernel powder		
	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS
T_1	8.21[a]	6.33[b] (22.89)	5.41[b] (34.10)	8.13[a]	5.31[c] (34.68)	4.31[ab] (46.98)	8.13[a]	4.86[b] (40.22)	3.46[b] (46.98)
T_2	8.21[a]	4.51[e] (45.06)	3.14[d] (61.75)	8.13[a]	4.49[e] (44.77)	2.36[c] (70.97)	8.13[a]	1.83[f] (77.49)	0.77[e] (90.52)
T_3	8.21[a]	4.95[d] (39.70)	4.07[c] (50.42)	8.13[a]	5.80[b] (28.65)	4.07[ab] (49.93)	8.13[a]	4.18[d] (48.58)	3.28[c] (59.65)
T_4	8.21[a]	6.70[a] (18.39)	5.50[ab] (33.00)	8.13[a]	4.92[d] (39.48)	4.16[ab] (48.83)	8.13[a]	4.68[c] (42.43)	3.34[ab] (58.91)
T_5	8.21[a]	6.76[a] (17.66)	5.78[a] (29.59)	8.13[a]	6.24[a] (23.24)	4.62[a] (43.17)	8.13[a]	5.21[a] (35.91)	4.06[a] (50.06)
T_6	8.21[a]	5.91[c] (28.01)	3.76[c] (54.20)	8.13[a]	6.15[ab] (24.35)	4.30[ab] (47.10)	8.13[a]	3.21[e] (60.51)	1.80[d] (77.85)
Control	8.08[a]	6.20[b] (23.26)	5.16[b] (36.13)	7.95[b]	5.20[d] (34.59)	3.98[b] (49.93)	7.95[b]	4.58[c] (42.38)	3.43[ab] (56.85)

(*Values with different superscript differ significantly*) **MAS**: Months after storage

The values represent average of three replications

Values in brackets shows the percentage loss of oil content with respect to initial

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried packaged in 250 gauge polyethylene bags

Table 4.11a. Effect of packaging materials on oleoresin content of harvested nutmeg during storage

Treatments	Oleoresin content (%)								
	Mace			Nut			Kernel powder		
	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS
T_1	22.40[a]	17.60[bc] (21.42)	16.20[b] (27.67)	29.09[a]	26.05[c] (10.45)	24.98[c] (14.12)	29.09[a]	26.33[c] (9.48)	23.68[c] (18.59)
T_2	22.40[a]	15.55[d] (30.58)	11.78[e] (47.41)	29.09[a]	25.41[d] (12.65)	24.08[e] (17.22)	29.09[a]	23.70[e] (18.52)	20.76[f] (28.63)
T_3	22.40[a]	17.20[c] (23.21)	15.28[c] (31.78)	29.09[a]	27.41[a] (5.77)	26.12[a] (10.20)	29.09[a]	25.86[c] (11.10)	22.76[d] (21.76)
T_4	22.40[a]	18.21[b] (18.70)	16.81[a] (24.95)	29.09[a]	26.63[b] (8.45)	25.44[b] (12.54)	29.09[a]	27.00[b] (7.18)	24.96[b] (14.19)
T_5	22.40[a]	19.27[a] (13.97)	17.31[a] (22.72)	29.09[a]	27.56[a] (5.25)	26.27[a] (9.69)	29.09[a]	27.88[a] (4.15)	25.47[a] (12.44)
T_6	22.40[a]	16.23[d] (27.54)	12.41[d] (44.59)	29.09[a]	27.30[a] (6.15)	25.90[a] (10.96)	29.09[a]	24.96[d] (14.19)	22.18[e] (23.75)
Control	21.56[a]	17.23[c] (20.08)	15.86[b] (26.43)	28.70[a]	25.34[d] (11.70)	24.49[d] (14.66)	28.70[a]	25.89[c] (9.79)	23.20[cd] (19.16)

(*Values with different superscript differ significantly*) **MAS**: Months after storage

The values represent average of three replications

Values in brackets shows the percentage loss of oleoresin content with respect to initial

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

Table 4.11b. Effect of packaging materials on oleoresin content of fallen nutmeg during storage

Treatments	Oleoresin content (%)								
	Mace			Nut			Kernel powder		
	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS
T_1	22.06^a	17.44^c (20.94)	16.06^{bc} (27.19)	29.63^a	26.10^c (11.91)	25.33^b (14.51)	29.63^a	26.40^b (10.90)	23.48^b (20.75)
T_2	22.06^a	15.41^e (30.14)	11.58^e (47.50)	29.63^a	25.61^d (13.56)	24.30^c (17.98)	29.63^a	23.83^d (19.57)	20.80^e (29.80)
T_3	22.06^a	17.08^c (22.57)	15.20^d (31.09)	29.63^a	27.43^a (7.42)	26.30^a (11.23)	29.63^a	26.00^{bc} (12.25)	22.96^c (22.51)
T_4	22.06^a	18.05^b (18.17)	16.50^b (25.20)	29.63^a	26.80^b (9.55)	25.48^b (14.00)	29.63^a	27.14^a (8.40)	25.40^a (14.27)
T_5	22.06^a	19.06^a (13.59)	17.21^a (21.98)	29.63^a	27.66^a (6.64)	26.37^a (11.00)	29.63^a	27.83^a (6.07)	25.60^a (13.60)
T_6	22.06^a	16.08^d (27.10)	12.06^e (45.33)	29.63^a	27.53^a (7.08)	25.71^b (13.22)	29.63^a	25.36^c (14.41)	22.60^d (23.72)
Control	21.40^b	17.10^c (20.09)	15.73^c (26.49)	29.13^b	25.46^d (12.59)	24.33^c (16.47)	29.13^b	25.86^{bc} (11.22)	23.33^{bc} (19.91)

(*Values with different superscript differ significantly*) **MAS**: Months after storage

The values represent average of three replications
Values in brackets shows the percentage loss oleoresin content with respect to initial

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

4.3.4 Enumeration of total microbial population

Growth of microbial population is a major problem during storage in spices as it decreases the quality. So, proper prevention against the growth of microbes should be taken before storage. The microbial populations of the stored samples were assessed at trimonthly intervals for a period of six months and the results are presented in table 4.12 to 4.14. An increase in microbial population was observed throughout the storage period irrespective of the packaging material and product. Bacteria, fungi and actinomycetes were the major groups of microorganisms observed in stored samples of spices.

4.3.4.1 Microbial growth in harvested nutmeg

Initially, the microbial populations were very less but as the storage advanced microbial populations increased steadily and maximum microbial populations were observed after six months of storage in all the samples irrespective of packaging materials. After six months of storage least microbial populations were observed in aluminum packs and maximum in gunny bags.

4.3.4.1.1 Bacteria

Initial bacterial population of harvested nutmeg was $0.33x10^6$ cfu/g in mace, $0.66x10^6$ cfu/g in nut and $1.33x10^6$ cfu/g in kernel powder. When all the samples stored in different packaging materials were compared it was found that maximum bacterial population (20.66 cfu/g) was observed in kernel powder stored in T_2 (gunny bags) and least in nut samples (0.75 cfu/g) stored in T_5 (aluminum laminated pouches).

4.3.4.1.2 Fungi

Fungal population also increased considerably and maximum population was observed after six months of storage in gunny bag stored samples ($11.83x10^3$ cfu/g in mace, $6.68x10^3$ cfu/g in nut and $14.83x10^3$ cfu/g in kernel powder) and least population was observed in samples stored in aluminium laminated pouches (0.866×10^3 cfu/g in mace, 0.83×10^3 cfu/g in nut and 3.00×10^3 cfu/g in kernel powder.

4.3.4.1.3 Actinomycetes

Initially actinomycetes population was completely absent but as the storage advanced their presence was also noticed. It was observed that actinomycetes population was maximum in gunny bag stored samples (4.66×10^5 cfu/g in mace and 4.96×10^5 cfu/g in nut) and least in samples stored in aluminium laminated pouches (0.83×10^5 cfu/g in mace and 0.33×10^5 cfu/g in nut). In case of kernel powder also maximum actinomycetes population was observed in gunny bag stored samples (5.33×10^5 cfu/g) and least in aluminium laminated pouches (1.33×10^5 cfu/g).

4.3.4.2 Microbial growth in fallen nutmeg

The initial bacterial population of fallen nutmeg was 1.33×10^6 cfu/g, 1.66×10^6 cfu/g and 2.66×10^6 cfu/g in mace, nut and kernel powder respectively and initial fungal population was 1.66×10^3 cfu/g in mace, 1.33×10^3 cfu/g in nut and 2.66×10^3 cfu/g in kernel powder. Initially actinomycetes population was less and it was recorded 0.33×10^5 cfu/g in mace, 0.66×10^5 cfu/g in nut and 0.66×10^5 cfu/g in kernel powder.

4.3.4.2.1 Bacteria

The initial bacterial population increased gradually and after six months of storage, maximum bacterial population of 14.83×10^6 cfu/g in mace, 20.66×10^6 cfu/g in nut and 26.67×10^6 cfu/g in kernel powder was observed in gunny bags and least bacterial population (2.33×10^6 cfu/g, 2.66×10^6 cfu/g and 4.33×10^6 cfu/g in mace, nut and kernel powder respectively) was observed in aluminium laminated pouches. The control samples showed just lower bacterial population than gunny bag samples.

4.3.4.2.2 Fungi

Total fungal population also increased considerably and maximum fungal population ($12.16x10^3$ cfu/g in mace, $20.50x10^3$ cfu/g in nut and $25.50x10^3$ cfu/g in kernel powder) was observed in gunny bags and least fungal population ($2.53x10^3$ cfu/g in mace, $2.16x10^3$ cfu/g in nut and $3.53x10^3$ cfu/g in kernel powder) was observed in aluminium laminated pouches after six months of storage.

4.3.4.2.3 Actinomycetes

Actinomycetes population was comparatively less before storage but increased during storage and samples stored in gunny bags showed highest actinomycetes populations ($10.66x10^5$ cfu/g in mace, $11.83x10^5$ cfu/g in nut and $8.00x10^5$ cfu/g in kernel powder) after six months of storage and at the same time least actinomycetes population ($1.33x10^5$ cfu/g, $1.5x10^5$ cfu/g and $1.66x10^5$ cfu/g in mace, nut and kernel powder respectively) was observed in aluminium laminated pouches.

When harvested and fallen nutmeg samples were compared higher microbial populations were observed in fallen nutmeg than in harvested nutmeg. This could be due to the high microbial load in fallen nutmeg before storage. Likewise the control samples (nutmeg without pretreatment) packaged in polyethylene bags showed higher microbial populations than the pretreated nutmeg packaged in the similar material.

4.3.5 Sensory evaluation

The sensory evaluation was carried out on a nine point hedonic scale using score card for four attributes namely colour, aroma, appearance and overall acceptability during storage. Each character was scored on the scale and the total scores calculated out of thirty six. As the fallen nutmeg mace is of poor quality sensory evaluation was done only for harvested nutmeg mace.

Table 4.12. Effect of packaging materials on microbial population of nutmeg mace during storage

Treatments	Total microbial count in cfu/g								
	Bacteria (x 10^6)			Fungi (x 10^3)			Actinomycetes (x 10^5)		
	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS
	Harvested nutmeg mace								
T_1	0.33^b	3.16^c	4.50^c	0.66^b	2.66^d	4.33^c	0	2.16^b	3.00^c
T_2	0.33^b	7.16^a	9.16^a	0.66^b	9.00^a	11.83^a	0	3.33^a	4.66^a
T_3	0.33^b	1.66^d	3.00^d	0.66^b	1.66^e	3.33^d	0	1.33^c	2.66^c
T_4	0.33^b	1.33^d	2.16^d	0.66^b	1.16^f	2.16^e	0	0.66^d	2.00^d
T_5	0.33^b	0.33^e	0.83^e	0.66^b	0.86^f	1.33^f	0	0.33^d	0.83^e
T_6	0.33^b	5.66^b	7.66^b	0.66^b	6.50^b	9.83^b	0	3.00^a	3.66^b
Control	2.16^a	4.83^b	7.75^b	1.83^a	4.00^c	9.00^b	0	3.16^a	4.33^a
	Fallen nutmeg mace								
T_1	1.33^a	5.83^d	7.33^d	1.66^a	6.50^c	8.50^c	0.33^a	5.50^c	7.03^c
T_2	1.33^a	10.50^a	14.83^a	1.66^a	9.50^a	12.16^a	0.33^a	8.83^a	10.66^a
T_3	1.33^a	4.16^e	6.16^e	1.66^a	5.33^d	7.66^{cd}	0.33^a	4.00^d	5.83^d
T_4	1.33^a	3.66^e	5.16^f	1.66^a	4.33^e	7.00^d	0.33^a	3.00^e	5.00^d
T_5	1.33^a	1.65^f	2.33^f	1.66^a	2.33^e	2.53^e	0.33^a	0.83^f	1.33^e
T_6	1.33^a	6.66^c	9.16^c	1.66^a	8.33^b	9.50^b	0.33^a	6.66^b	8.33^b
Control	2.50^b	7.66^b	12.66^b	2.33^a	7.16^c	10.33^b	1.00^a	7.33^b	9.16^b

(*Values with different superscript differ significantly*)

MAS: Months after storage

The values represent average of three replications

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

Table 4.13. Effect of packaging materials on microbial population of nutmeg nut during storage

Treatments	Total microbial count in cfu/g								
	Bacteria (x 10^6)			Fungi (x 10^3)			Actinomycetes (x10^5)		
	Harvested nut								
	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS
T_1	0.66^b	3.66^c	5.34^c	0.66^b	2.16^c	5.33^b	0.00	2.33^b	3.83^b
T_2	0.66^b	7.33^a	10.83^a	0.66^b	4.00^a	6.68^a	0.00	3.02^a	4.96^a
T_3	0.66^b	3.25^{cd}	4.34^{cd}	0.66^b	1.55^d	3.16^c	0.00	1.66^c	3.00^c
T_4	0.66^b	1.83^e	2.83^{ef}	0.66^b	1.25^d	1.75^d	0.00	0.83^d	1.83^d
T_5	0.66^b	0.66^f	0.83^f	0.66^b	0.75^e	1.83^d	0.00	0.00^e	0.33^e
T_6	0.66^b	2.50^{de}	3.66^{de}	0.66^b	1.16^d	2.75^c	0.00	1.33^{cd}	2.33^{cd}
Control	2.00^a	5.75^b	7.66^b	2.66^a	3.00^b	6.50^a	0.50	3.00^a	4.50^{ab}
	Fallen nut								
T_1	1.6^a	9.25^b	17.16^c	1.3^a	7.3^c	13.0^c	0.66^a	6.0^d	8.16^{cd}
T_2	1.6^a	13.16^a	21.50^a	1.3^a	11.16^a	20.5^a	0.66^a	9.3^a	11.83^a
T_3	1.6^a	5.83^c	8.16^e	1.3^a	5.7^d	9.50^d	0.66^a	5.0^e	7.33^d
T_4	1.6^a	3.66^d	5.83^f	1.3^a	4.66^e	7.83^e	0.66^a	3.83^f	6.0^e
T_5	1.6^a	2.33^d	2.6^g	1.3^a	1.5^f	2.16f	0.66^a	1.16^g	1.5f
T_6	1.6^a	6.50^c	11.8^d	1.3^a	8.50^b	14.83^b	0.66^a	8.0^b	10.8^b
Control	2.33^a	10.0^b	19.50^b	2.33^a	9.3^b	14.33^b	1.50^a	7.0^c	8.83^c

The values represent average of three replications **MAS**: Months after storage

(*Values with different superscript differ significantly*) The values represent average of three replications

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bag

Table 4.14. Effect of packaging materials on microbial population of nutmeg kernel powder during storage

Treatments	Bacteria (x 10^6)			Fungi (x 10^3)			Actinomycetes (x10^5)		
	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS	Initial	3 MAS	6 MAS
	Kernel powder from harvested nutmeg								
T_1	1.33^a	8.34^c	15.33^{bc}	2.00^a	5.33^c	6.83^{cd}	0.33^a	3.33^{bc}	4.16^b
T_2	1.33^a	12.83^a	20.66^a	2.00^a	9.50^a	14.83^a	0.33^a	4.00^{ab}	5.33^a
T_3	1.33^a	5.33^d	7.66^e	2.00^a	3.16^e	5.50^d	0.33^a	1.84^{ef}	2.66^d
T_4	1.33^a	6.18^d	13.00^d	2.00^a	4.33^d	6.16^d	0.33^a	2.83^{cd}	3.33^c
T_5	1.33^a	1.83^e	2.83^f	2.00^a	2.33^f	3.00^e	0.33^a	0.66^f	1.33^e
T_6	1.33^a	9.83^b	16.50^b	2.00^a	6.16^b	8.66^b	0.33^a	2.50^d	2.83^d
Control	2.00^a	8.33^c	14.75^c	2.83^a	5.33^c	7.75^{bc}	0.33^a	4.16^a	5.66^a
	Kernel powder from fallen nutmeg								
T_1	2.66^a	10.33^{bc}	17.16^c	2.66^a	9.66^c	12.66^d	0.66^a	5.50^c	$6.16b^c$
T_2	2.66^a	13.50^a	26.67^a	2.66^a	14.50^a	25.50^a	0.66^a	7.16^a	8.00^a
T_3	2.66^a	7.33^{de}	13.00^d	2.66^a	7.00^e	9.00^e	0.66^a	4.50^d	5.66^c
T_4	2.66^a	8.66^c	16.16^c	2.66^a	8.33^d	11.16^d	0.66^a	3.66^{de}	5.66^c
T_5	2.66^a	3.16^e	4.33^e	2.66^a	3.33^f	3.53^e	0.66^a	0.83^f	1.66^d
T_6	2.66^a	12.00^{ab}	23.00^b	2.66^a	11.16^b	17.66^b	0.66^a	6.83^{ab}	7.50^{ab}
Control	3.50^a	12.66^a	21.50^b	3.66^a	11.50^b	14.83^c	1.66^a	6.00^{bc}	8.00^a

(*Values with different superscript differ significantly*)

MAS: Months after storage

The values represent average of three replications

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

4.3.5.1 Sensory evaluation of harvested nutmeg mace

Before storage, total sensory score of harvested nutmeg mace was 32.8 and during storage total sensory score of mace was decreased compared to initial score. Mace stored in T_5 (aluminum laminated pouches) showed highest total sensory score (29.8) and (26.3) after three months and six months of storage respectively, followed by (27.4) in T_6 (metal container) after three months of storage and (24.8) in T_3 (N_2 packaging) after six months of storage and least total sensory score (13.4) and (8.4) after three months and six months of storage respectively was recorded in T_2 (gunny bag). Mace packed in gunny bag showed drastic reduction in sensory score than other packaging materials. Highest mean rank for overall acceptability was observed in aluminium laminated pouches (5.35) followed by N_2 packaging (5.20) and least mean rank was observed in gunny bag (1.00). Kendall's coefficients of concordance among the judges on all the characteristics were highly significant (Table 4.15).

Table 4.15. Sensory evaluation of harvested nutmeg mace during storage in different packaging materials

Treatments	Colour		Aroma		Appearance		Overall acceptability		Total score	
	3 MAS	6 MAS	3 MAS	6 MAS	3 MAS	6 MAS	3 MAS	6 MAS	3 MAS	6 MAS
T_1	6.8 (3.75)	5.8 (3.60)	6.6 (3.70)	5.8 (4.20)	6.1 (3.85)	5.2 (3.55)	6.1 (3.95)	5.1 (3.45)	25.6	21.9
T_2	2.9 (1.00)	2.1 (1.00)	4.8 (1.35)	2.7 (1.10)	2.8 (1.00)	1.8 (1.00)	2.9 (1.00)	1.8 (1.00)	13.4	8.4
T_3	7.0 (4.05)	6.0 (4.05)	7.5 (5.50)	6.7 (5.65)	6.9 (5.10)	6.0 (4.95)	6.9 (5.40)	6.1 (5.35)	28.3	24.8
T_4	7.3 (4.70)	6.4 (4.65)	6.9 (4.35)	6.0 (4.60)	6.2 (3.95)	5.6 (4.35)	6.2 (4.00)	5.9 (4.95)	26.6	23.9
T_5	7.8 (5.60)	6.9 (5.90)	7.8 (6.05)	7.0 (6.10)	7.1 (5.55)	6.3 (5.75)	7.1 (5.60)	6.1 (5.35)	29.8	26.3
T_6	7.5 (5.20)	6.9 (5.60)	6.5 (3.50)	5.0 (2.75)	6.9 (5.20)	6.2 (5.40)	6.5 (4.55)	5.7 (4.60)	27.4	23.8
Control	6.8 (3.70)	5.4 (3.20)	6.4 (3.55)	5.3 (3.60)	5.9 (3.35)	4.9 (3.00)	6.0 (3.50)	5.0 (3.45)	25.1	20.6
Kendall's coefficint	0.578*	0.648*	0.557*	0.685*	0.589*	0.669*	0.547*	0.558*		

Values represent average of 14 judges
Values in the parenthesis represent mean rank
* Significant

Sensory score before storage

Character	T_1-T_6	
Aroma	8.1	7.6
Appearance	8.1	7.7
Overall acceptability	8.1	7.5
Total score	32.8	30.2

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

DISCUSSION

5. DISCUSSION

Nutmeg, an important tree spice crop grown mainly in Kerala, is widely used as a flavouring agent in food preparations and also in folk medicines. Nutmeg provides two products viz. the nutmeg (dried seed) and the mace (dried aril covering the seed). Nutmeg and its oleoresins are used in the preparation of meat products, soups, sauces, baked foods, confectioneries, puddings, seasoning of meat and vegetables, to flavour milk dishes and punches. Mace is used to flavour milk based sauces and processed products like sausages, soups, pickles, ketchups, chutneys etc. Nutmeg oil and mace oil are used mainly in flavouring soft drinks, canned foods and meat products.

In some tribal areas of India, as a part of conventional medicine, nutmeg is used for treating diabetes, as well as other ailments such as diarrhoea, mouth sores and insomnia. It proves to be an excellent tonic for the cardiovascular system. It increases the blood circulation and stimulates the heart functions. Nutmeg oil is a great liver tonic, as it can remove the toxins therein. Myristicin, the active principle of nutmeg, has demonstrated extraordinary effects in the protection of hepatocytes or liver cells. It is also helpful in treating kidney infections and dissolving kidney stones. It is also antiseptic in nature and hence it is used in many kinds of toothpaste. Research supports the use of nutmeg as a preservative and an anti-septic agent.

As the peak harvest season of nutmeg in Kerala falls during the active monsoon period, always there could be chances to have heavy load of microbes accompanying with the produce, besides the farmers also face the problem of drying the produce to a safer moisture level due to the lack of proper sun shine. Improper drying and packaging lead to microbial growth and results in the deterioration of the produce. Any lot detected for aflatoxin will automatically get rejected during export. Presence of aflatoxin is due to the growth of *Aspergillus sp.*and the growth of these organisms occurs due to the increased water activity in the dried produce. Therefore, proper drying to safer moisture level followed with proper packaging is an inevitable part of good manufacture.

Considering the above mentioned problems in nutmeg, an attempt has been made to develop an ideal pretreatment, drying and storage method for nutmeg and the results of experiments conducted are discussed in this chapter.

5.1 STANDARDIZATION OF PRETREATMENT

During rainy season, the soil as well as air-borne micro flora is very active and as a result of this, nutmeg collected in this season could be with high initial microbial load. The high initial microbial load results in the decay of produce unless properly dried. Even the resting spores of bacteria and fungi proliferate in storage if the produce regains the moisture. So in order to reduce the initial microbial load in nutmeg, standardization of pretreatment was conducted and results are discussed here.

5.1.1 Initial microbial load of nutmeg

Results clearly indicated that fallen nutmeg showed higher initial microbial load than harvested nutmeg. This is because of the fact that fallen nutmeg was in contact with the decaying soil for a longer period of time than harvested nutmeg. Compared to fallen nut with mace, fallen nut without mace showed high microbial load, again due to the longer contact with soil and by the time mace would have completely decayed (Fig.6).

5.1.2 Microbial load after pretreatments

Nutmeg washed in 1000 ppm alum water for two minutes showed maximum reduction in microbial load followed by nutmeg washed in 100 ppm chlorine water than other treatments. The maximum reduction of microbial load in alum water pretreated and chlorine water pretreated nutmeg than blanching could

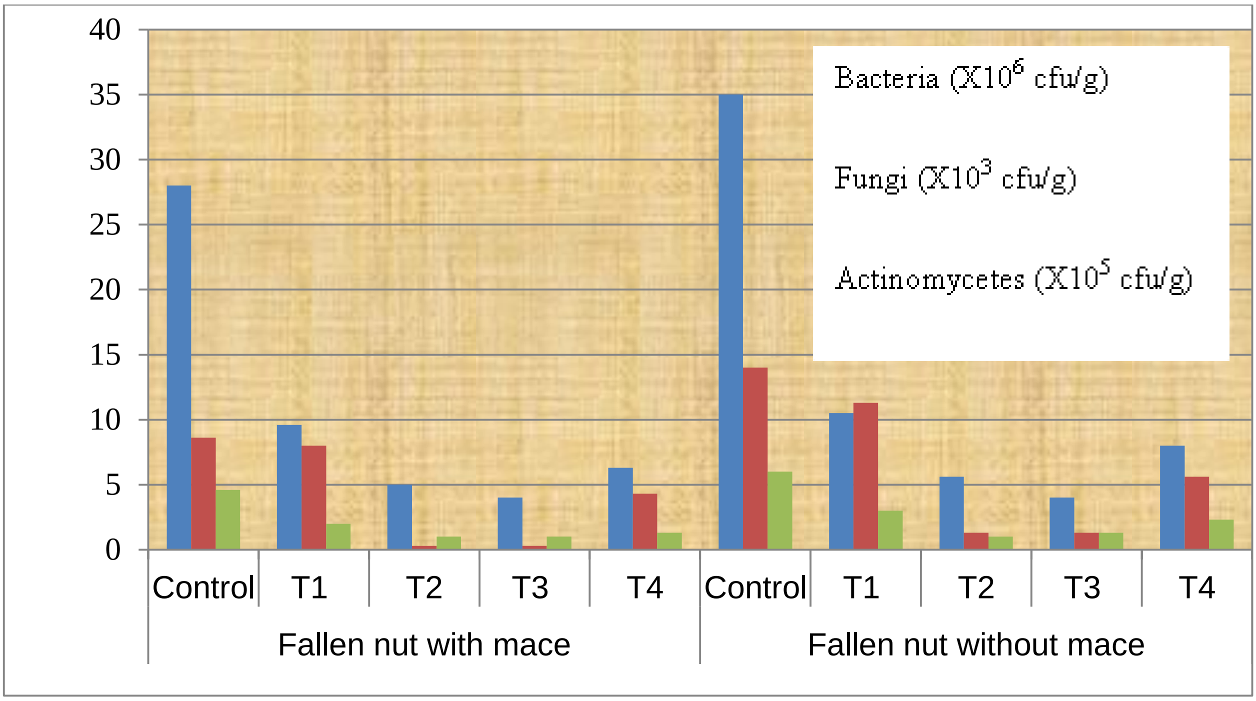


Fig.6. Effect of pretreatments on microbial population of fallen nutmeg samples

Control: Without pretreatment

T_1: Washing in plain running water for two minutes

T_2: Washing with luke warm water containing 100 ppm chlorine for two minutes

T_3: Washing with luke warm water containing 1000 ppm alum for two minutes

T_4: Blanching in hot water at 75-80^{0}C for two minutes

be due to the added effect of disinfectant action of these chemicals apart from blanching effect. This result is in agreement with the findings of Indian Institute of Spices Research (IISR), Calicut. According to Sproul (1974), coagulation-flocculation and sedimentation with alum and iron can achieve microbial reductions of 90 to 99 per cent for all classes of waterborne pathogens under optimum conditions. According to Oo and Aung (1993), addition of 500 mg/L (500 ppm) potash alum to water in traditional storage vessels (160 L capacity) reduced the fecal coliform contamination by 90 to 98 per cent and consumer acceptance of the treated water was also high.

5.1.3 Colour and appearance changes due to pretreatments

Colour is one of the important attributes of the nutmeg and pretreated nutmeg showed good colour and appearance than nutmeg without pretreatment. This could be due to the fact that pretreatment resulted in washing away of any adherent soil particles and debris. Compared to fallen nutmeg, harvested nutmeg was superior in terms of colour, appearance and wholesomeness. Similar result was reported by Chikkanna (2008). He stated that nutmeg mace blanched in hot water at a temperature of 75^0C for two minutes showed good quality of dried mace.

5.2 DRYING STUDIES

Majority of spices and herbs are perishable in their fresh state because of high water activity and may deteriorate within a few days after harvest unless dried to a safer moisture level of 10 to 12 per cent. One of the ancient and best ways to preserve the plant products is to dry them in order to conserve their desirable qualities, reduce storage volume and extend shelf life. Moisture plays a crucial role in the keeping quality of any dried material. Usually spices and herbs are harvested at a moisture percentage of 60 to 70 per cent on wet basis. During drying, moisture content gets reduced to a lower level and for proper storage moisture content should be less than 12 per cent. The drying method that provides rapid reduction in the moisture content without affecting the quality of spices is considered to be the best method. Therefore an attempt has been taken to dry the nutmeg by adopting conventional drying methods like sun drying and country oven drying and by improved methods like mechanical drying and bulb drying (drying under the close vicinity of 60 watt burning bulbs) with an aim to reduce the drying time and improve quality.

During drying, both mace and nut from harvested as well as fallen nutmeg were tried in combination with four types of drying methods and results obtained are discussed here.

5.2.1 Recovery percentage

Since removal of water reduces the weight of the material, higher recovery percentage indicates higher moisture content of the sample. Higher recovery percentage of the sun dried samples (both harvested and fallen nutmeg) was due to their higher residual moisture percentage. Least recovery percentage of bulb dried and mechanically dried nutmeg was due to efficient and continuous drying with higher temperature (70^0C to 72^0C in bulb drying and 50^0C to 60^0C in mechanical drying) and lesser residual moisture content.

As the mace is having delicate structure and more surface area than nut, least recovery percentage was noticed in it. The heat transfer and mass transfer during drying will depend basically on the increased surface area. Higher surface area leads to maximum escape of moisture leading to low recovery. Higher recovery percentage of nut was due to lower water content in it (wet basis) but higher bio mass. These results are in accordance with the findings of Manjusha (2012) who reported that chopped materials of Kizharnelli gave lesser recovery percentage compared to whole plant.

However the margin of variation in recovery percentage of nutmeg under different methods was very less but sun dried nutmeg showed higher recovery percentage. It could be due to low temperatures (23.9^{0}C to 30.1^{0}C) prevailed during the drying of nutmeg (Fig.7).

5.2.2 Residual moisture

Residual moisture content reflects the microbial quality of a dried product. Residual moisture content was high in sun dried nutmeg (Fig.8). The least residual moisture percentage of mace dried in a mechanical drier was due to low recovery which was explained above. These findings are similar to that of Gauniyal *et al.* (1988) who found that roots and whole plant samples with thicker texture and lesser area exposed to a drying agent, recorded more moisture in shade and sun drying and lower moisture for mechanical drying. Manjusha (2012) also reported similar results in the case of drying of Kizharnelli.

5.2.3 Drying rate

Drying rate influences the efficiency of a drying method. Drying rate depends on the drying temperature, initial moisture content and texture of the plant material. Drying rates of different plant materials in different drying methods were illustrated by drying curves. Harvested nutmeg mace showed initial faster rate of drying compared to that of fallen nutmeg mace (Fig. 1-5). Higher temperature and higher surface area will result in higher rate of drying. This is the reason why faster rate of drying was recorded in nutmeg dried under burning bulbs at 72^{0}C to 76^{0}C followed by oven drying at 65^{0}C to 68^{0}C. The slower drying rate of nut was due to its less moisture content and also the hard seed shell hinders the process of drying. These results are in accordance with the findings of Gopalakrishnan *et al*. (1980) who reported that sun drying of mace takes about 12 to 16 hours under open sun but only five to six hours in mechanical drying. Jayashree *et al*. (2010) also reported that drying of mace in an air flow drier took 300 to 330 minutes to dry to a safer moisture level of six per cent. Yuvaraj (2007) reported that *Wedelia chinensis,* when dried mechanically has the highest rate of drying compared to sun and shade drying. Padmapriya *et al.* (2009) also reported

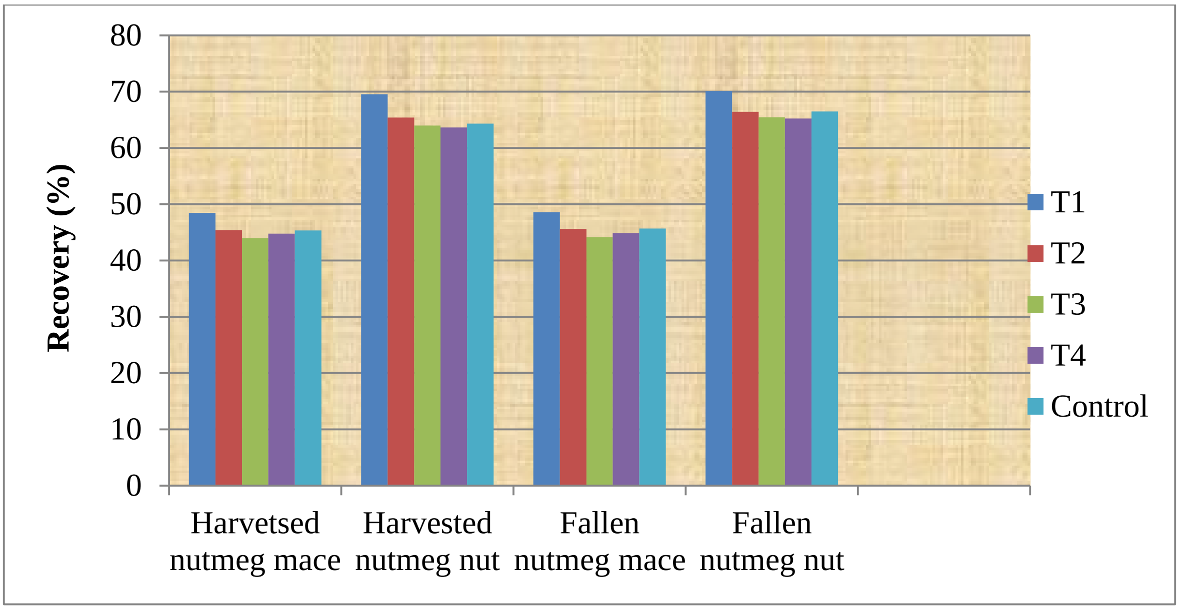


Fig.7. Effect of drying methods on recovery percentage of dried nutmeg

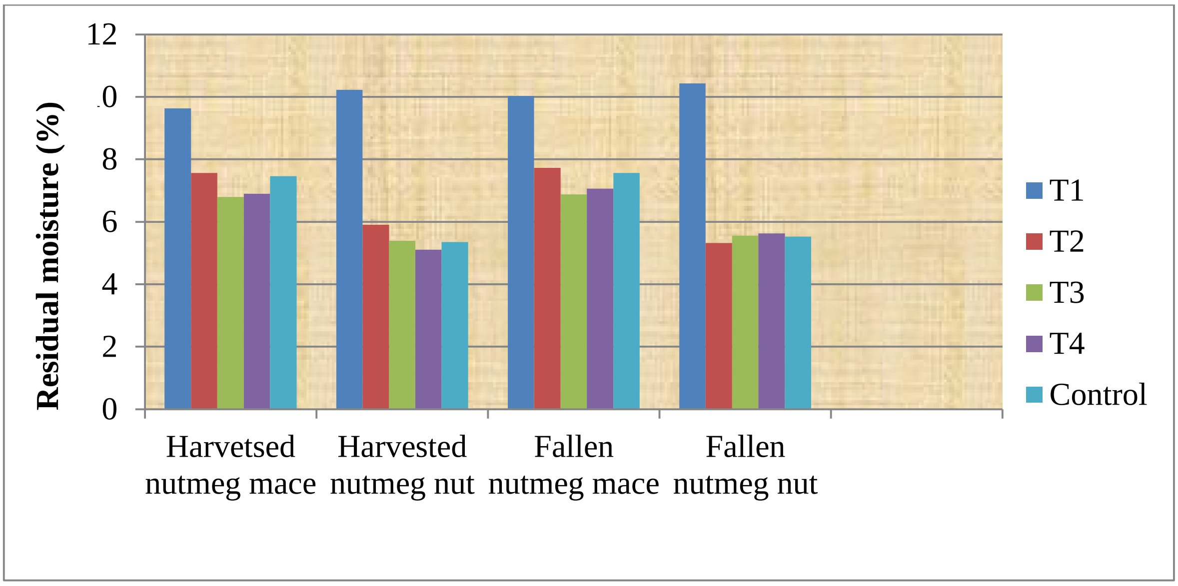


Fig.8. Effect of drying methods on residual moisture percentage of dried nutmeg

T_1: Sun drying

T_2: Oven drying

T_3: Bulb drying

T_4: Mechanical drying

Control: Nutmeg without pretreatment but mechanically dried

that sun drying of *Tinosporia cordifolia* required longer period than mechanical drying and the highest drying rate was observed in mechanical drying of smallest stem bits. Similar results were also obtained by Mehta *et al.* (2005). They did comparative evaluation of different drying methods like sun drying, solar drying, shade drying and tray drying at 60°C for drying liquorice (*Glycyrrhiza glabra*) and reported that tray drying recorded the shortest time of 36 hours followed by solar drying (52 hours), sun drying (64 hours) and shade drying (76 hours).

5.2.4 Colour change

Colour is one of the important attributes of a dried material. Prolonged exposure of materials to sunlight or to higher temperature will result in change in colour of the product. Bulb dried mace showed bleached appearance because of high temperature during drying whereas country oven dried mace showed darkened appearance because of smoke coming out from drier. But good orange red colour retention was found in mechanically dried nutmeg. Slight mould growth was observed in sun dried mace because of slow drying rate and problem of rewetting. These results are in accordance with the findings of Chikkanna (2008) who reported that mace dried in a developed drier (mechanical drier) showed better appearance than sun dried mace and the later showed mould growth also.

5.2.5 Oil and oleoresin

Oil and oleoresin are the two important products from nutmeg. Herbs and spices are the most sensitive to drying processes which increases deterioration of constituents viz. loss of volatiles, flavours, changes in colour, texture and decrease in nutritional value. Drying time and temperature have profound influence on the oil and oleoresin content of any spice product and prolonged exposure to higher temperature results in the loss of oleoresin and oil. The higher recovery of oil and oleoresin from mechanically dried nutmeg was probably due to the less temperature employed (50^0C to 60^0C) than country oven drying and bulb drying

(68^0C to 72^0C). The less recovery of oil and oleoresin from sun dried nutmeg was probably due to prolonged exposure to sun drying (Fig. 9 & 10). This result is in corroboration with the findings of Chikkanna (2008) who reported that nutmeg dried in a developed drier (mechanical drier) is of superior quality in terms of oil and oleoresin recovery than sun dried nutmeg. He also reported that myristicin content is also more in mechanically dried nutmeg than sun dried nutmeg. Athmaselvi (2009) also reported similar results in case of turmeric that drying turmeric rhizomes in a mechanical drier at 60°C showed higher percentage of curcumin, oleoresin and essential oil contents than drying under the sun.

5.2.6 Microbial population of dried nutmeg

Microbial quality of spices and herbs depends on initial microbial population and drying method also, as the different drying methods yielded the product with different residual moisture content. Higher the residual moisture content in the products higher will be the microbial population. This is the reason why nutmeg dried under sun showed higher microbial population than other methods. More over during sun drying, nutmeg is exposed to outside environment which ultimately resulted in the contamination of the product. Mechanically dried and bulb dried nutmeg showed least microbial population because the drying chamber is closed and free from extraneous contaminants. The high microbial population of nutmeg without pretreatment could be due to the fact that it contains high initial microbial population. Fallen nutmeg samples showed higher microbial population than harvested nutmeg samples because initially they contained higher microbial population. This result is in accordance with the findings of Chikkanna (2008) who reported that sun dried nutmeg showed mould growth. Joy (2000) also reported that extraneous matter, insect infected, whole insects dead and mould content were very high in commercially dried nutmeg (sun dried) whereas it was absent in solar tunnel dried nutmeg.

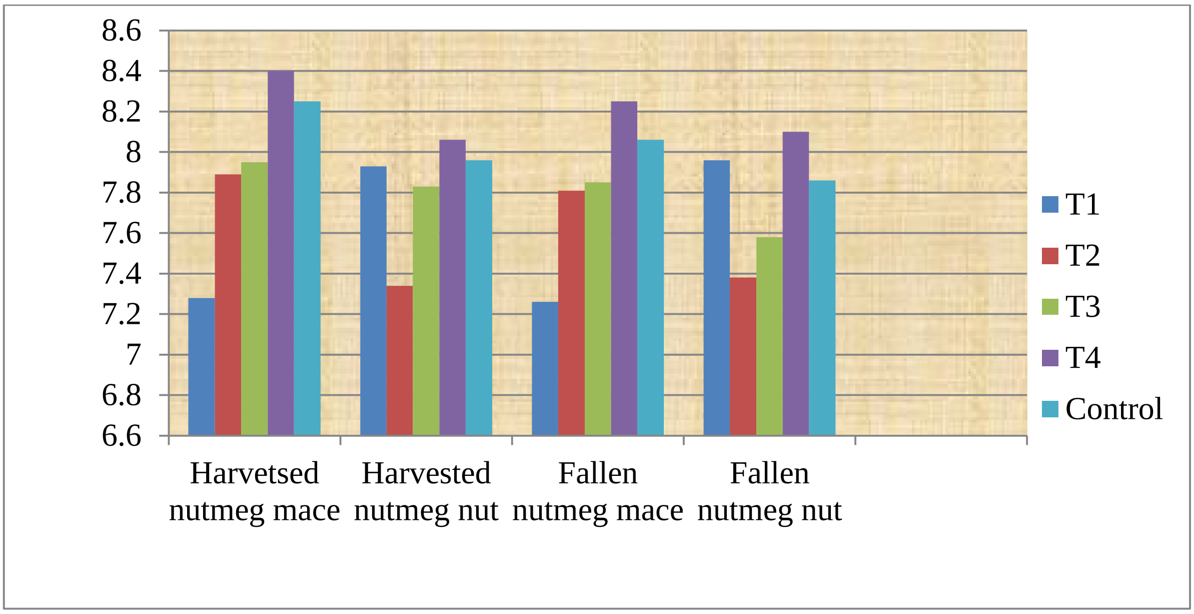


Fig.9. Effect of drying methods on oil content of nutmeg

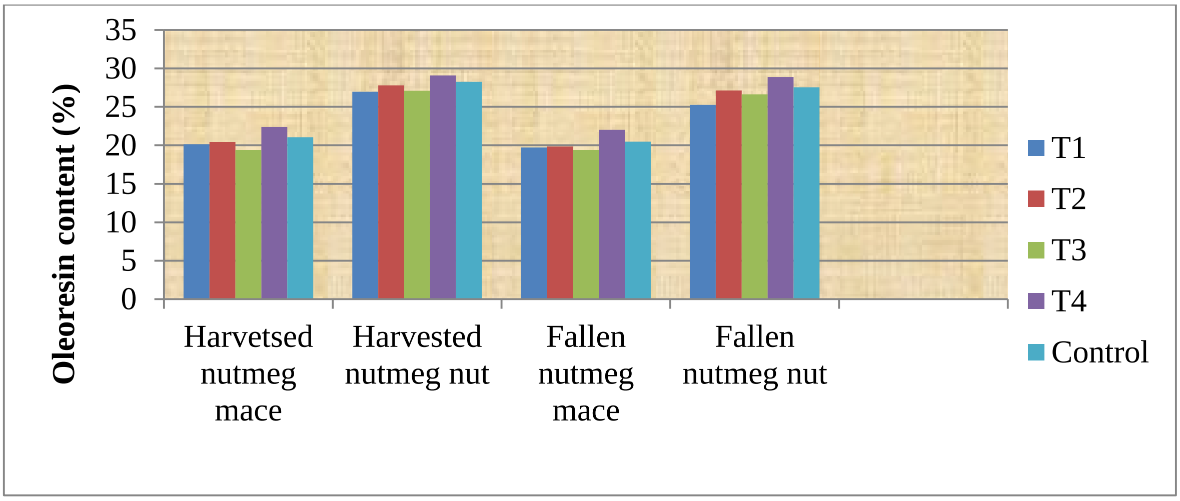


Fig.10. Effect of drying methods on oleoresin content of nutmeg

T_1: Sun drying

T_2: Oven drying

T_3: Bulb drying

T_4: Mechanical drying

Control: Nutmeg without pretreatment but mechanically dried

5.2.7 Sensory quality

Mace is strongly aromatic resinous and warm in taste and generally said to have a finer aroma than nutmeg. Sensory evaluation of mace showed that mace dried in a mechanical drier is of good quality than in other methods. This could be due to uniform drying of mace at low temperature. Bulb drying and sun drying resulted in bleached appearance of mace hence lowest sensory score for colour was observed in them whereas oven drying resulted in the slight deposition of soot in mace. Control samples (nutmeg without pretreatment but mechanically dried) showed less total sensory score than pretreated samples dried in a mechanical drier because pretreatment resulted in washing away of any adherent soil and dirt particles and so good appearance after drying. Harvested nutmeg mace showed higher sensory scores than fallen nutmeg mace because of fresh appearance and wholesomeness (Fig.11a, 11b & 12). This result is in accordance with the findings of Dandamrongrak *et al*. (2003) who reported that sensory quality (colour) of blanched banana dried in a heat pump dehumidifier dryer at 50^0C is greater than un blanched banana.

5.3 PACKAGING AND STORAGE STUDIES

Dried materials unless protected from further absorption of moisture will not maintain its quality. Storage of any produce is of utmost importance as inappropriate storage conditions may render the produce unusable, no matter with what care it has been harvested and processed. For safer storage of dried materials the moisture will have to be maintained always below 12 per cent.

The packaging material must provide protection from heat, humidity and temperature and at the same time it should not contaminate the produce. Packaging is a means of producing the correct environmental conditions for food during the length of its storage and/or distribution. The atmospheric oxygencan deteriorate the dried foods through the oxidative phenomenon that it produces.

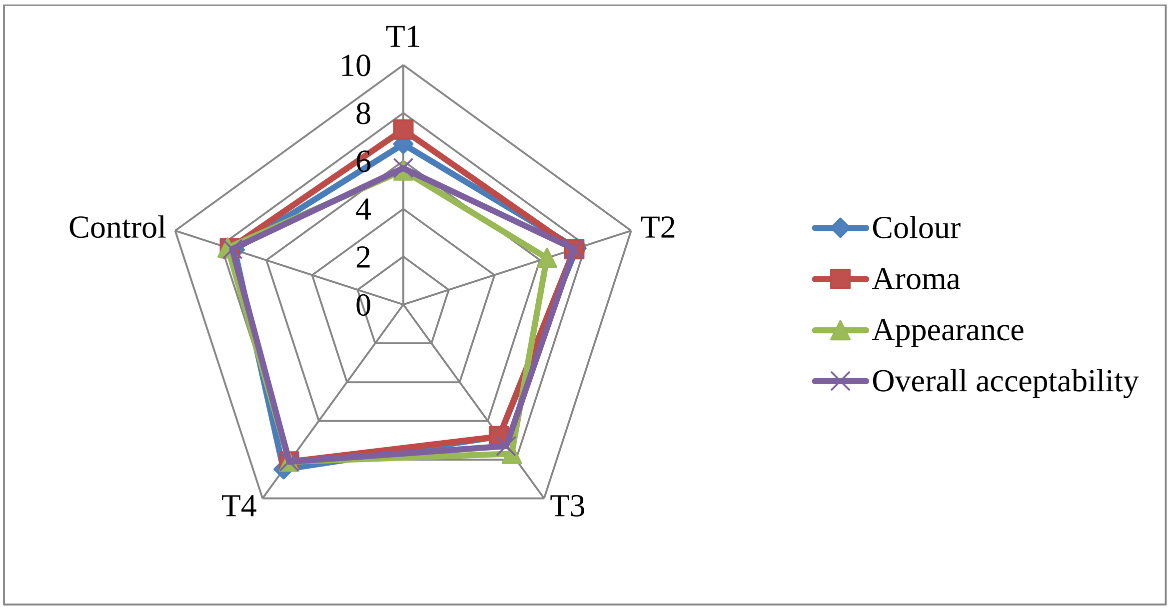


Fig.11a. Organoleptic characters of harvested nutmeg mace dried under different drying methods

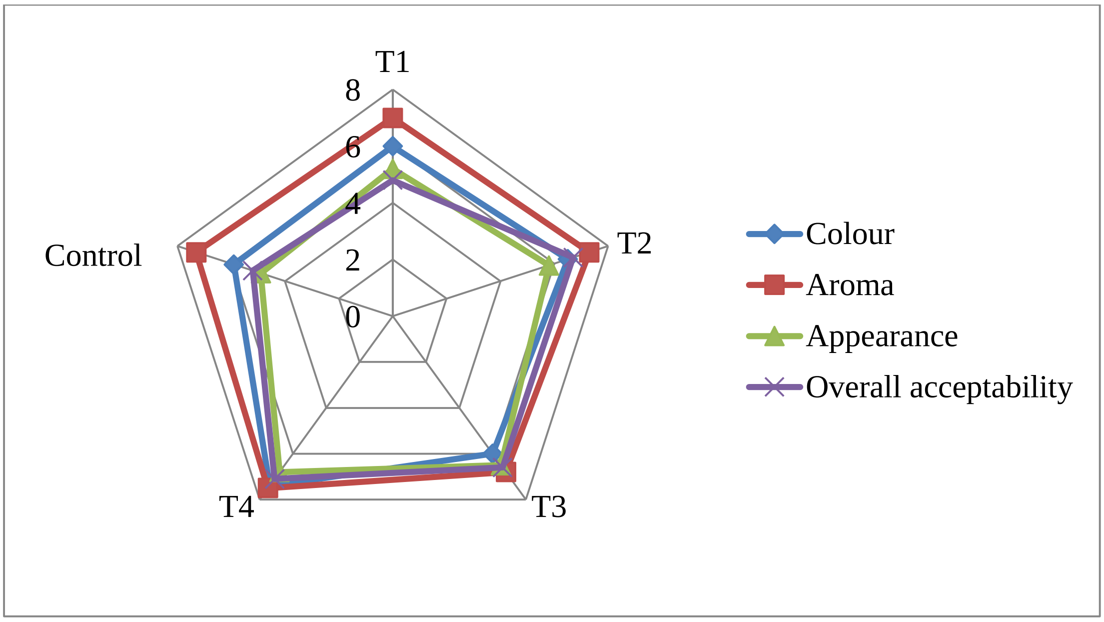


Fig.11b. Organoleptic characters of fallen nutmeg mace dried under different drying methods

T_1: Sun drying

T_2: Oven drying

T_3**:** Bulb drying

T_4: Mechanical drying

Control: Nutmeg without pretreatment but mechanically dried

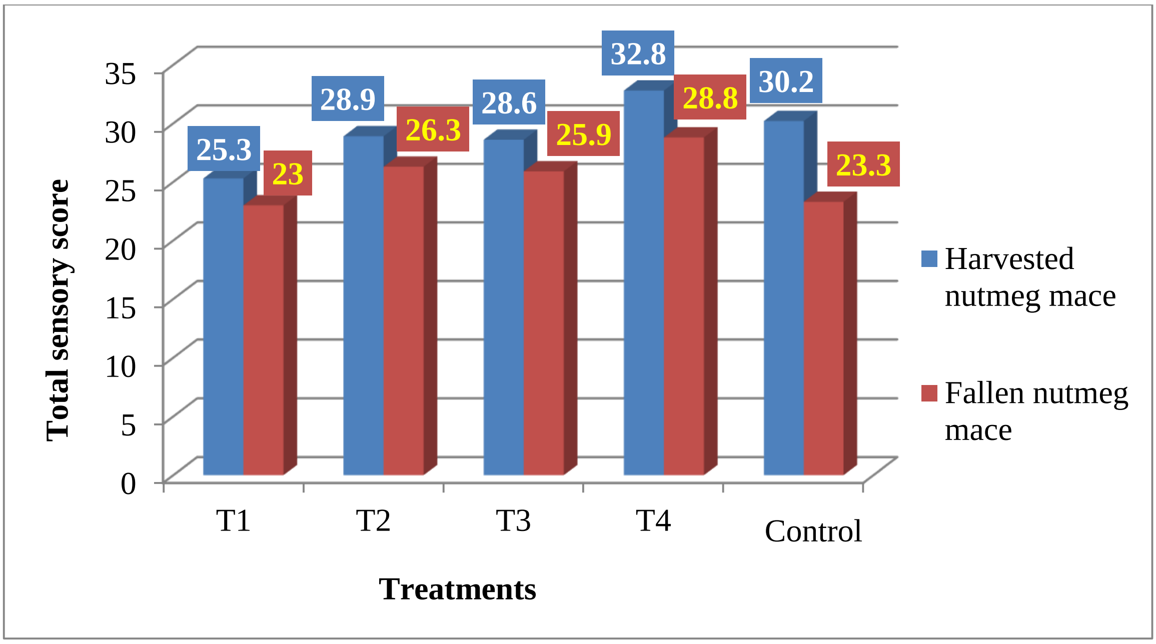


Fig.12. Effect of drying methods on total sensory score of dried nutmeg mace

T_1: Sun drying

T_2: Oven drying

T_3**:** Bulb drying

T_4: Mechanical drying

Control: Nutmeg without pretreatment but mechanically dried

The action of oxygen can be eliminated by employing packaging methods like vacuum packing, flushing with N_2 and CO_2.

Pattanshetty *et al.* (1979) reported that the moisture, time and packing material have definite combined effect on the chemical content of the products and the changes become rapid and significant after 3 to 4 months of storage. Therefore, dried nutmeg materials were packaged in different containers and assessed for quality deteriorations during storage and the results are discussed here.

5.3.1 Percentage of residual moisture

Dried materials always tend to go back to its original state. Therefore, depending upon the availability of moisture around the dried product and the extent of barrier proofness of the packaging materials, a variation in the moisture pick up will be observed. Though progressive moisture absorption was noted in all the samples stored in different packaging materials, samples packaged in aluminium laminated pouches showed least ingress of moisture than all other packaging materials after six months of storage (Fig.13). It is due to the high moisture proof property of aluminium laminate. This outcome is well supported by the findings of Pua *et al*. (2008) who found that jackfruit powder packaged in aluminium laminated polythene showed least increase in moisture during storage.

5.3.2 Oil and oleoresin content

Retention of chemical constituents during storage is an important factor which determines the shelf life of the plant material. Oil and oleoresin contents were reduced highly in the samples stored in gunny bag with the advancement of storage period but well preserved in aluminium laminated pouches. A drastic reduction in the oil and oleoresin content of samples stored in gunny bag could be due to higher moisture content in the samples. Higher the moisture content, lesser is the shelf life and hence the quality also showed deterioration. High oil and oleoresin retention in samples stored in aluminium laminated pouches is due to its high barrier proof properties against air and moisture (Fig. 14 and 15). Drastic reduction in oil and oleoresin contents of kernel powder than nut could be due to the fact that in case of nut, the kernel is well protected from atmospheric air and moisture by means of shell which prevents auto oxidation whereas kernel powder with increased surface area is exposed to atmospheric air and sunlight leading to loss of volatile compounds. Similar results were obtained by Madan *et al.* (2008) also. They reported that the saponin content in the powdered samples of *Asparagus racemosus* tubers was maximum in airtight bags at the end of storage period. Sruthi and Maya (2012) also reported similar results in the case of storage of mace and concluded that aluminium packaging materials are best for long term retention of oil and oleoresin content.

5.3.3 Enumeration of total microorganisms

Spices and herbs are subjected to deterioration by microbial activities during the harvesting, processing, storage and their distribution. Spices and herbs are often associated with a wide range of microorganisms, which may be soil-borne, air-borne or water-borne. Among them, bacteria and fungi dominate more than the other organisms. Contamination of spices and herbs with toxins like mycotoxins produced by pathogenic microflora has been reported. Microbiological background depends on several environmental factors and exerts an important effect on overall quality of herbal products and product preparations (Kniefel *et al.* 2002). Drying the raw materials to safe moisture level and proper storage using suitable packages is one of the eco-friendly measures to protect the materials from microbes. Results of the study on the quantitative analysis of microbes in the dried samples of nutmeg stored in different packaging materials are discussed here.

The initial enumeration of samples prior to storage itself showed certain colonies of both fungi and bacteria even after drying. However, the population was considerably low and these organisms are either soil-borne or air-borne.

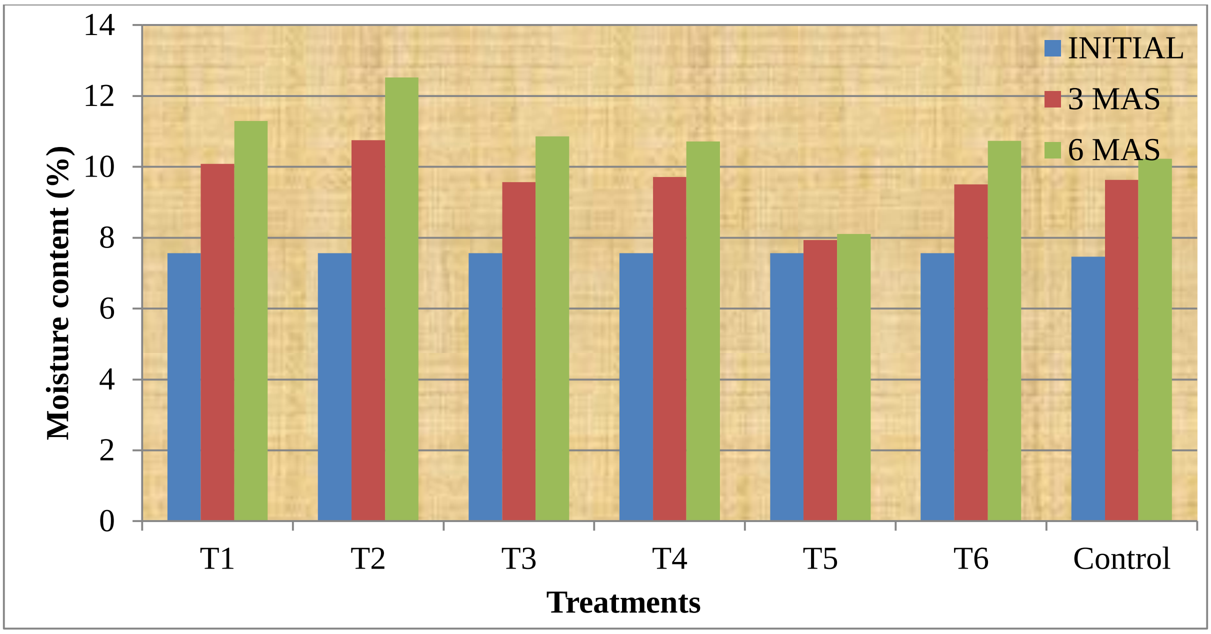


Fig.13. Effect of packaging materials on residual moisture percentage of harvested nutmeg mace during storage

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

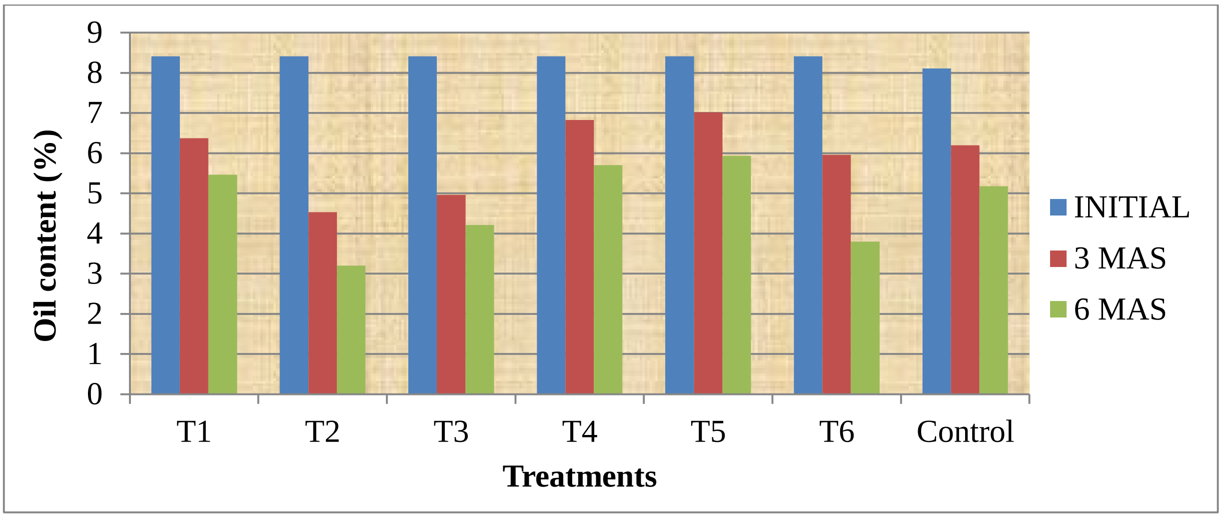


Fig.14. Effect of packaging materials on oil content of harvested nutmeg mace during storage

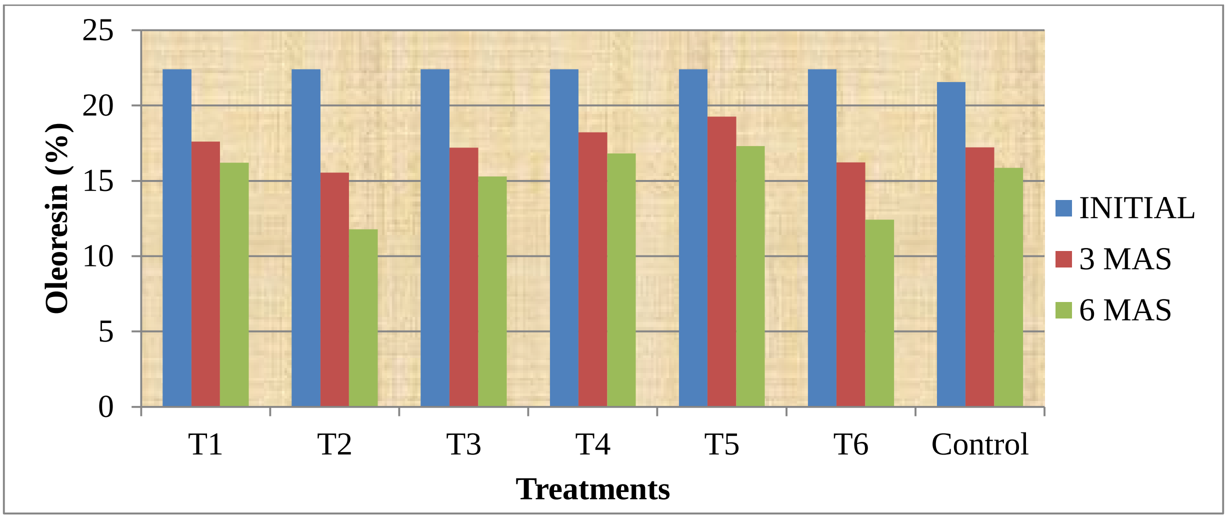


Fig.15. Effect of packaging materials on oleoresin content of harvested nutmeg mace during storage

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

These results are in accordance with the findings of Kniefel *et al.* (2002) who reported that the harvested medicinal plants harbor many microbes and some may be found even after drying. The actinomycetes population of the dried sample before storage was absent as the distribution of actinomycetes is erratic, that is, it can be present in great number or almost totally absent.

In the present study, a gradual increase in the moisture content followed with increased microbial populations of the samples were observed during storage. According to Bera *et al*. (2001), the growth of microorganisms in food samples was influenced by moisture content, higher or lower relative humidity, temperature of storage and type of samples. The increased bacterial and fungal population in the samples can be correlated with the increase in moisture content during storage. Less microbial population in the samples packaged in aluminum laminated pouches is due to barrier proofness of aluminum laminate to moisture and air (Fig.16a-17b). It is supported by the findings of Negi *et al.* (2012). They reported that aluminium laminated package recorded lesser microbial colonies than polyethylene packages. High microbial population was observed in gunny bag packaged samples after six months of storage. This could be due to high moisture ingress in gunny bags during storage. Sujatha (2002) also reported similar results in the case of storage of Adhatoda and reported that samples stored in gunny bags showed maximum microbial growth.

Increase in the residual moisture with the advancement of storage period will increase the water activity. Increased water activity will prompt the growth of microorganisms, the variations in the growth is due to the variations in the packaging materials used, thus after six months of storage, a drastic change in the microbial population was observed in all the samples, including the growth of actinomycetes. Further, it was also observed by Jha (1998) that relatively dry substances can even support the growth of certain organisms like *Penicillium* and *Aspergillus* and proliferates under storage. Therefore, the increase in the microbial load with the advancement of storage is phenomenal. When the total microbial populations of harvested and fallen nutmeg were compared after six months of storage, it was seen that the population was higher in fallen nutmeg. This may be due to high initial microbial load of fallen nutmeg after drying.

After six months of storage, the control samples (nutmeg without pretreatment but mechanically dried) packaged in 250 gauge polyethylene showed higher microbial population than pretreated nutmeg in the same packaging material. This could be due to high initial microbial population in the control samples.

5.3.4 Sensory evaluation

Mace packaged in aluminium foil laminated pouches and N_2 packages remained organoleptically acceptable even after six months of storage whereas mace packaged in gunny bag was organoleptically not acceptable after three months of storage. The good barrier properties of aluminium foil laminated pouches reduced the chemical and microbial deterioration of the mace therefore it showed good sensory scores (Fig.18). The less appearance score in vacuum packaged samples was due to crushing of mace in the process of vacuum creation. Ranganna (1995) stated that vacuum packaging was not advisable for fruit powders due to the compression and caking of particles. The less aroma score in metal container packaged samples was due to the development of slight metallic flavour in the samples.

The highest score for overall acceptability recorded by the aluminium and N_2 packs were due to the better retention of colour, aroma and appearance. Mary (2005) observed that banana fruit powder packaged in aluminium foil laminate with N_2 packaging showed higher sensory scores for overall acceptability even after 12 months of storage. Similar results were reported by Rahman *et al*. (2007) also in storage studies of coriander. They observed that coriander powder packaged in heat sealable laminated aluminium film showed good sensory quality even after 12 months of storage whereas HDPE (High Density Polyethylene) film showed good sensory quality for ten months and PP (Polypropylene) film showed good sensory quality for four months only.

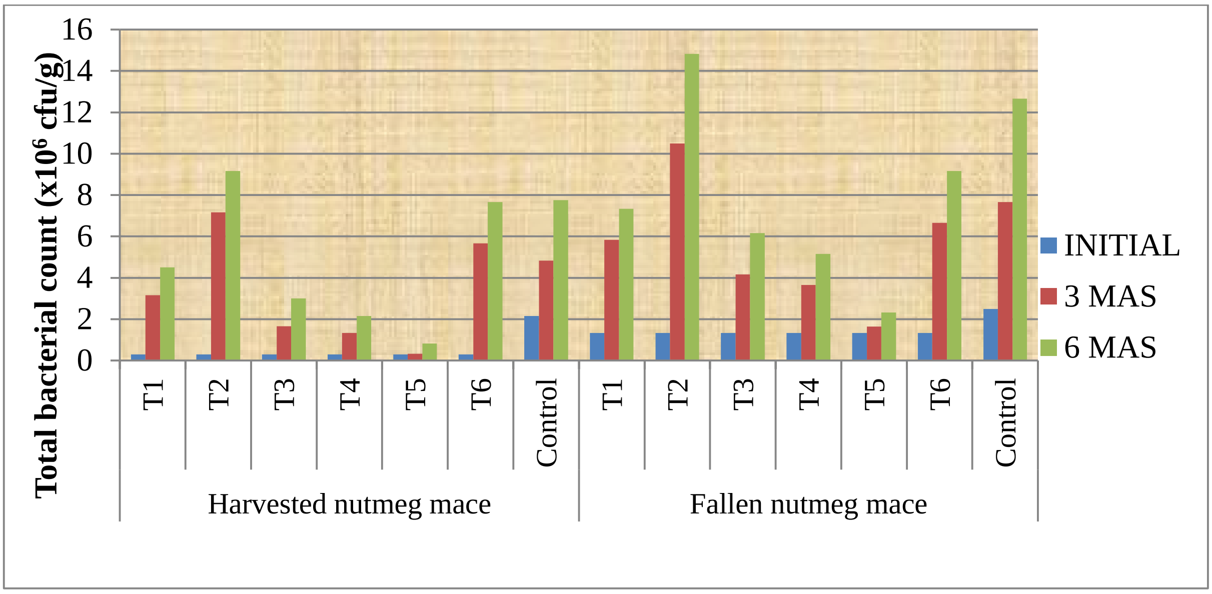


Fig.16a. Effect of packaging materials on bacterial population of nutmeg mace during storage

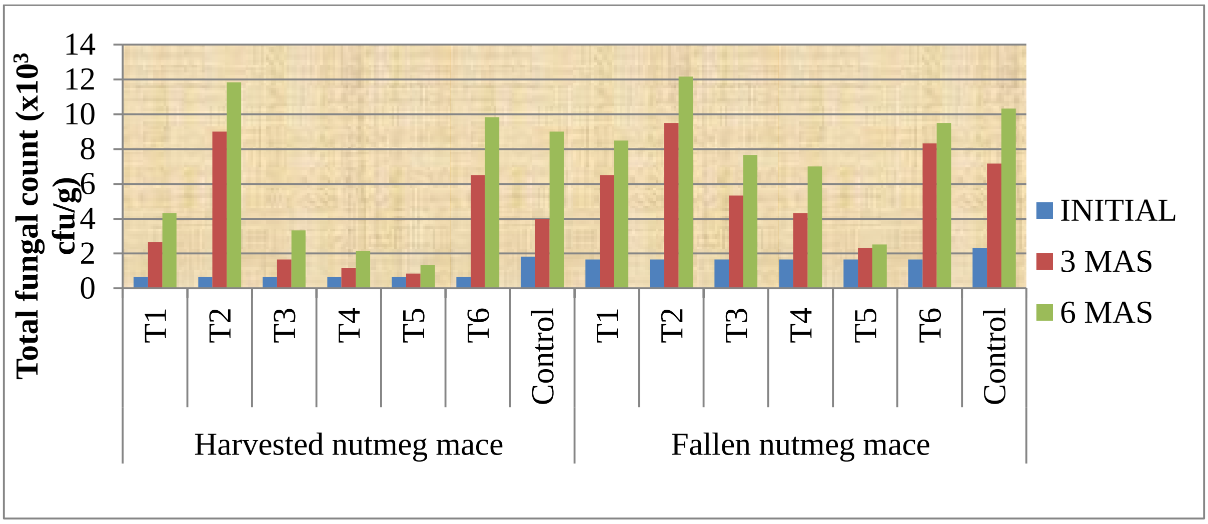


Fig.16b. Effect of packaging materials on fungal population of nutmeg mace during storage

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

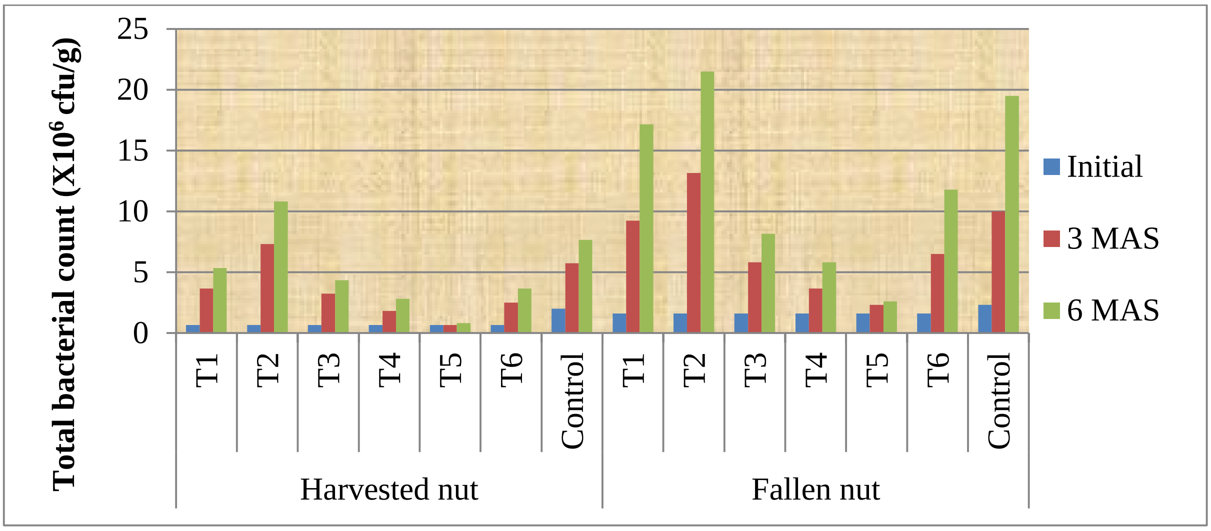


Fig.17a. Effect of packaging materials on bacterial population of nutmeg nut during storage

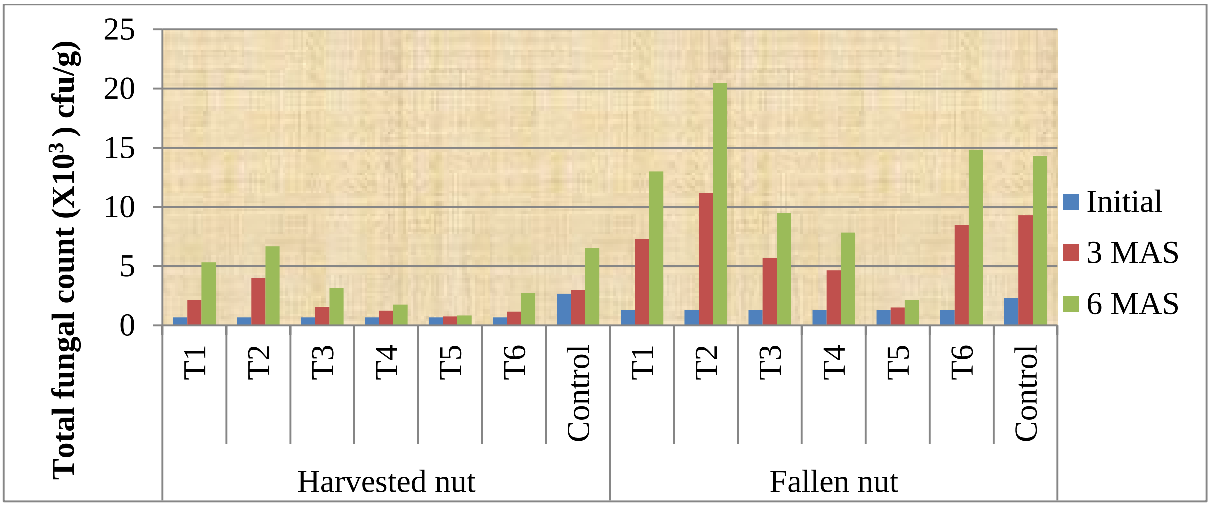


Fig.17b. Effect of packaging materials on fungal population of nutmeg nut during storage

T_1: Packaged in 250 gauge polyethylene bags
T_2: Packaged in 250 gauge polyethylene lined gunny bags
T_3: Packaged in 250 gauge polyethylene bags with N_2 gas
T_4: Vacuum packaged in 250 gauge polyethylene bags
T_5: Packaged in aluminium laminated pouches
T_6: Packaged in rigid metal containers
Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

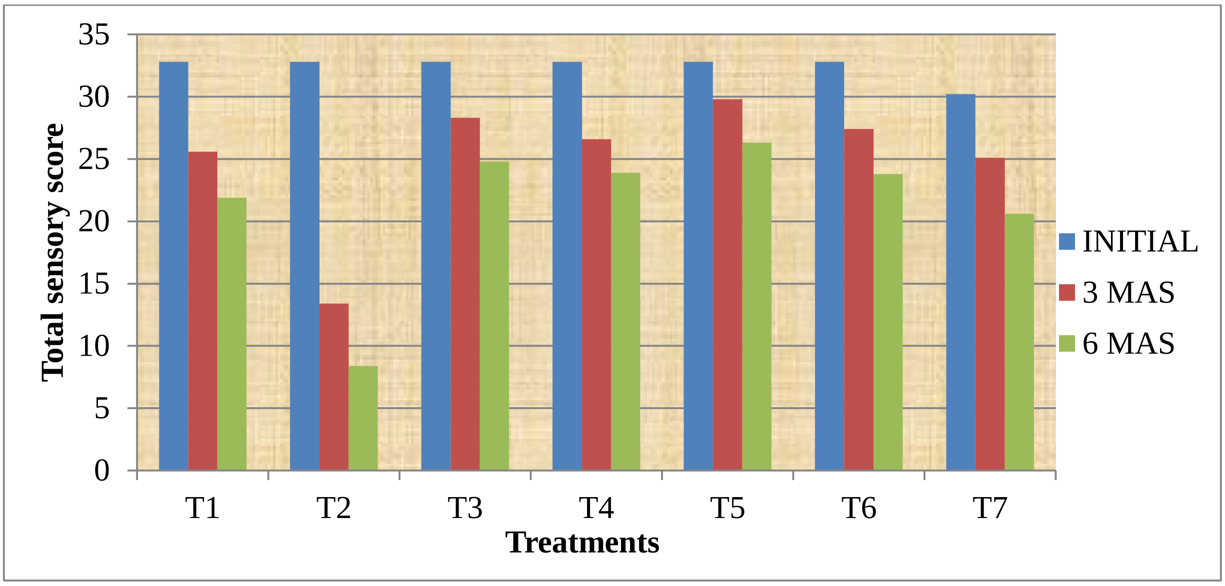


Fig.18. Total sensory score of harvested nutmeg mace during storage in different packaging materials

T_1: Packaged in 250 gauge polyethylene bags

T_2: Packaged in 250 gauge polyethylene lined gunny bags

T_3: Packaged in 250 gauge polyethylene bags with N_2 gas

T_4: Vacuum packaged in 250 gauge polyethylene bags

T_5: Packaged in aluminium laminated pouches

T_6: Packaged in rigid metal containers

Control: Nutmeg without pretreatment but mechanically dried and packaged in 250 gauge polyethylene bags

SUMMARY

6. SUMMARY

The study entitled "Drying and Storage Studies in nutmeg (*Myristica fragrans* Houtt.)" was conducted at Department of Processing Technology, College of Horticulture, Vellanikkara, during 2012-13. The objectives of the study were to develop a suitable pretreatment, drying and storage technique for nutmeg without degradation in quality. All the experiments were carried out in a Completely Randomised Design (CRD) with three replications.

Initial microbial load was assessed between the harvested nutmeg and those fallen naturally. Though microbial load was observed in both the cases, those fallen ones were contaminated heavily as they were in direct contact with the wet humus soil. Among the various pretreatments tried to reduce the initial microbial load, washing the produce in 1000 ppm alum water was found to be the best.

Drying studies were conducted by employing four methods of drying *viz*. sun drying, country oven drying, bulb drying and mechanical drying. Among them, mechanical drying was found to be the best method as it yielded uniform dried product with good colour and appearance. Mechanical drying took less time for drying of nutmeg (7 hours in case of mace and 18 hours in case of nut) compared to sun drying i.e.16 hours in case of mace and 56 hours (8 daysX7 hours) in case of nut. Maximum oleoresin (22.40% in mace and 29.09% in nut) and oil contents (8.40% in mace and 8.06% in nut) were also recorded in mechanically dried samples. Sensory evaluation also indicated, mechanically dried mace as the best as it showed highest total sensory score (32.8) whereas sun dried mace showed least total sensory score (25.3).

Nutmeg washed with 1000 ppm alum water and dried in a mechanical drier was selected for further storage studies. Three nutmeg products viz, mace, nut and kernel powder were employed. Both oil and oleoresin contents were found to get reduced with the advancement of storage period in all the products irrespective of the packaging materials. But the samples stored in aluminium

laminated pouches showed least reduction in oil and oleoresin content during storage.

Residual moisture content increased with the advancement of storage period in all the samples but samples stored in aluminium laminated pouches showed least ingress of moisture at the end of storage period.

Sensory evaluation revealed that mace stored in aluminium laminated pouches was the best as it showed highest total sensory score (26.3) whereas mace stored in gunny bags showed least total sensory score (8.4) after six months of storage.

Microbial populations were increased during storage in all the samples irrespective of packaging materials and maximum microbial populations were observed after six months of storage but the samples stored in aluminium laminated pouches showed least microbial populations where as samples stored in gunny bags showed highest microbial population. Among mace, nut and kernel powder, mace showed highest microbial population. During storage also harvested nutmeg showed less microbial populations than fallen nutmeg. Control samples (nutmeg without pretreatment but mechanically dried) stored in 250 gauge polyethylene showed higher microbial population than pretreated nutmeg stored in similar packaging material.

Thus harvested nutmeg washed with 1000 ppm alum water followed with mechanical drying and packaged in aluminium laminated pouches could retain the quality in its best form up to six months in ambient conditions.

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* Originals not seen

APPENDICES

APPENDIX I

WEATHER PARAMETERS PREVAILED DURING DRYING PERIOD

Weather Parameters	June 2012
Max. Temperature (^{0}C)	33.0
Min. Temperature (^{0}C)	23.0
Relative Humidity (Morning)%	94.00%
Relative Humidity (Noon)%	77.00%
Sunshine (hrs)	3.00

APPENDIX II

NUTRIENT COMPOSITION OF MEDIA

1. **Nutrient Agar Media** (for Bacteria)

Beef extract	3 g
Peptone	5 g
Sodium chloride	5 g
Agar	18 g
Distilled water	1000 ml
P^H	6.8-7.2

2. **Potato Dextrose Agar Media** (for Fungus)

Peeled potatoes	250 g
Dextrose	20 g
Agar	18 g
Distilled water	1000 ml
P^H	5.6

3. **Kenknight's Agar Media** (for Actinomycetes)

Glucose	1 g
$MgSO_4$	0.1 g
KCl	0.1 g
KH_2PO_4	0.1 g
Ammonium Sulphate	0.1 g
Agar	18 g
Distilled water	1000 ml
P^H	7

Appendix III

Score card for sensory evaluation of dried nutmeg mace

9 Point hedonic scale

Product code	Colour	Aroma	Appearance	Overall acceptability

Note: You are provided with the samples of nutmeg and you are requested to rank them according to the scale given below as per your liking.

Scale:

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

Date:

Name:
Signature:

Drying and storage studies in nutmeg (*Myristica fragrans* Houtt.)

By

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(2011-12-114)

ABSTRACT OF THE THESIS

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ABSTRACT

Nutmeg (*Myristica fragrans* Houtt.) known in Malayalam as 'Jathikka' is one of the most important spices grown in Kerala. Although nutmeg is available for harvest throughout the year, its peak harvest season lies in the months of June to August during which the soil microorganisms are also active and as a result, nutmeg collected in that season will be with high initial microbial load. Therefore an attempt has been made to reduce the initial microbial load and also to develop a suitable drying and storage technique for nutmeg.

In both harvested and fallen nutmeg, washing with 1000 ppm luke warm alum water was found effective in reducing high initial microbial load to a low level. Mechanical drying of nutmeg in a cabinet drier was found to be the best method of drying as it was quick and yielded the product with minimum loss of colour, oil and oleoresin. Total sensory score was also highest in cabinet dried samples.

Among the packaging materials tried aluminium foil laminated pouches were better than other packaging materials as the products stored in aluminium laminated pouches showed highest oil and oleoresin contents and at the same time least microbial population even after six months of storage. Highest total sensory score was also recorded in the mace samples stored in aluminium laminated pouches.

The techniques thus developed could be effectively used in reducing the high initial microbial load and also to store the materials for a longer period of time without much spoilage and quality deterioration.