DEVELOPMENT AND EVALUATION OF A CONVECTIVE TYPE DRYER FOR NUTMEG MACE

(*Myristica fragrans houtt)*

By

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DECLARATION

I hereby declare that this thesis entitled **"Development and Evaluation of a convective type dryer for Nutmeg mace"** is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Chikkanna, G.S.

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SYMBOLS AND ABBREVIATIONS

Art.	Article
Agrl.	Agricultural
AOAC	American Association of Analytical Chemists
g	gram
mg	milligram
ml	milliliter
°C	degree centigrade
Co	Company
GI	Galvanized iron
MS	Mild Steel
hp	horse power
rpm	revolutions per minute
h	hour
min	minute
nm	nanometre
µl	microlitre
d.b.	dry basis

%	per cent
α	alpha
Publ	publishing
β	beta
^{o}	degree
M.C	moisture content
kW	kilowatt
Fig.	figure
viz.	namely
wb	wet basis
et al.	and others
r	regression coefficient
Eqn.	Equation

Dedicated

To

Farming

Community

Introduction

CHAPTER I
INTRODUCTION

Spices play an important role in people's day to day diet. From time immemorial, people in many parts of the world have been using spices and herbs extensively to improve the flavor and aroma of food materials. Besides being used for flavoring, they are used also as food preservatives. India is considered the 'Home of Spices' owing to its favorable climatic and soil conditions. About only10 per cent of the spices produced in the country are used to meet the domestic demand and the 90 per cent exported which helps in earning a substantial amount of foreign exchange. India's share in the world spice market is estimated at 46 per cent by volume and 26 per cent by value (Peter and Rema, J. 2006). The reasons for this lower performance are that the country does not produce high quality spices that fetch good price and that the spices are exported without value addition. So, the country is required to concentrate on quality of spices and value addition.

Nutmeg mace (**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 spices (Pruthi, J.S.1979). Nutmeg is the dried seed, While Mace is the aril covering the outer surface of the seed. The yield of mace is about 15% that of nutmeg and it is the more expensive of the two spices. In India it is grown in the states of Kerala, Karnataka, Tamilnadu, Goa, Maharastara and Andaman Nicobar Islands. The fleshy 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). The mace, which is brilliant red in color, is somewhat tough and leathery.

This spice is widely used as condiments and 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). Mace is also used in ayurvedic medicine as a constituent in preparation of prevention of dental care (Hada, et.al.1988).

In India, the production of dried nutmeg mace, commercially, is confined exclusively to the state of Kerala. The annual production of nutmeg mace is estimated to be around 550 metric tones and the annual domestic's consumption of nutmeg mace in the country is estimated to be around 1100 metric tones. Thus during 2000-01, India imported over 75,000 kg of nutmeg valued at about Rs.7 lakhs and in addition nutmeg oil worth about Rs. 2 lakhs. (Anonymous, 1988).

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

Drying is the removal of moisture from any product. The keeping quality of spices depends much on drying and the moisture content should be kept between 10 to 12 per cent for most of the spices for better storage (Pruthi, J and Krishnamurthy, 1985). Even one percentage more than the critical moisture level may be affecting the quality of the 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.

The appearance, the contents of volatile oil and oleoresin, the pungency level and a subjective assessment of the aroma and flavor are important in the quality evaluation of dried Nutmeg 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.

Dried nutmeg and mace are used directly as spices and also for the preparation of their derivatives viz. the distilled oils and oleoresins which mainly consists of Myristicin

(76.8%) and elemicin (12.8%) (Mallavarapu and Ramesh,1998). Nutmeg and mace oleoresins, obtained by solvent extraction of the spices are used as flavoring and perfumery agents (Hallstorm and Thuvander, 1997). Nutmeg oil distilled from nutmegs finds the largest application in flavoring processed foods and soft drinks. The process of preparing dried nutmeg starts with the removal of the surrounding mace from the seed followed by the drying of seed and mace separately. During drying, the mace loses about 60 per cent of its weight as moisture (Goplakrishna,1992). If drying is delayed, mace becomes highly susceptible to mould and insect contamination.

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

Conventionally, mace is dried in the sun or in kitchen fire place utilizing the heat from the stove. Some farmers dry mace on clay kurdis or sand medium spread over fire. Conventional methods, of drying result in loss of some volatile oil by evaporation, destruction of some of the heat sensitive pungent constituents. It is also difficult to control the temperature of drying. Temperature has profound influence on the color of the dried mace. Conventionally dried mace does not posses uniform red color

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 color and contaminates mace with mould growth resulting in its poor appearance importance of a mechanical dryer, which is cost effective and gives a consistently high quality product. This method of drying could produce a uniformly clean product, with the maximum retention of volatile oil. In view of these, it was proposed to carry out a study entitled "**Development and Evaluation of a Convective Type Dryer for Nutmeg Mace**" with the following objectives:

1. To develop a suitable convective type dryer for Nutmeg mace.

2. Performance evaluation of the developed dryer.

3. To study the drying characteristics of Nutmeg mace using the developed dryer and compare them with those of conventional drying.

4. Quality analysis of the dried Nutmeg mace.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with a brief review of the crop, its characteristics and the research work carried out by various investigators on the production of dried mace. Also, different methods and technologies adopted for drying of spices are discussed. Structure and composition of Nutmeg and physical and chemical properties of spices have also been reviewed and discussed briefly.

2.0 Nutmeg mace

2.1 Origin

The Nutmeg, **Myristica fragrans Houtt.,** belongs to the family **Myristicaceae**, with about 18genera and 300 species. **Myristica** is the largest genus, of which lists 72 species. It is considered native of the eastern islands of the Mollucas. Purseglove *et.al* (1981) reported that the chromosome number in nutmeg is 2n=42, it is a spreading evergreen tree and normally attains a height of 8 to10m. Sometimes reaching up to 20m, although the roots are superficial. The bark of the stem is grayish black, the leaves alternate, glabrous and estipulate. The lamina is 5 to 15 cm long and 2 to 7 cm broad bright green to light green in color. On ripening the fruit bursts into two halves. The mace is seen as an attractive bright scarlet cage closely enveloping the hard, thin, black shining shell of the seed called Nutmeg. Mace is dried reticulate aril of nutmeg.

2.2 Climate and soil

Nutmeg is basically a tropical plant hence it prefer a warm and humid climate. It is grown and produces satisfactorily within annual temperature range of 24 to 29^{0}C with 91% relative humidity. It can be successfully grown as a rain fed crop in areas receiving annual rainfall in the range of 1500-3000 mm with a dry period of

2-3 months. It is found to grow up to 750 m latitude in Indian conditions, however, it grows best at lower elevations and it does not thrive above prescribed elevation. The nutmeg thrives well in sheltered valleys or hot moist tropical islands at elevations from sea level to 100m altitude, Shanmugavelu and Madhva Rao (1977).

The nutmeg is best grown in river banks with much silt. It grows well in alluvium deep friable loam soil in Indian conditions, Johnkutty (1988).

2.3 Varieties

There are two basic types of nutmeg available in world trade viz. West Indian and East Indian types. The West Indian variety is grown in the islands of Grenada and Trindia. The East Indian variety is mainly grown in India like Kerala, Karnataka and Maharastara. The East Indian nutmegs are highly aromatic and superior and mace has a brilliant orange color, possessing a characteristic flavor (Anonymous,1988).

2.4 Composition of Nutmeg and Mace

Table 2.1: Nutritive value of Nutmeg and Mace per 100g.

Content	Nutmeg	Mace
Moisture	14.3g	15.9g
Protein	7.5g	6.5g
Ether extraction(fat)	36.4g	24.4g
carbohydrate	28.5g	47.8g
Fiber	11.6g	3.8g
Minerals	1.7g	1.6g
Calcium	120mg	180mg
Phosphorus	140mg	100mg
Iron	4.6mg	12.6mg

VitB1	0.33mg	0.35mg
VitB2	0.01mg	0.42mg
Niacin	1.4mg	1.4mg

(Ref:Gopalan et al., 1981)

Pruthi (1979) reported that nutmeg also contains a Volatile oil (6-16%), Starch (14.6-24.2%), Pentasans (2.25%), Furfural (1.5%)) and Pectin (0.5-0.6%). Mace contains a volatile oil (4-15%), Amylo dextrin (25%), Reducing sugar, Pectin, Resins and coloring matter etc.

Hada et al., (1987) observed new 8 neolignans and 5 lignans from the aril of nutmeg (mace).

Pruthi and Krishnamurthy (1985) recorded 93% of good quality pectin from nutmeg pericarp.

2.5 Harvesting and yields

A seedling tree begins to bear fruits when 5 to 8 years old. Trees propagated vegetatively by marcotts or inarching fruit earlier. Yield gradually increases in age of the plant up to 15 years or longer and continue for 30 to 40 years thereafter it stabilizes. The fruit ripen in about 6 to 9 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, although some fruits ripen throughout the year.

Nazeem *et.al.*, 1981, observe that hand pollination increases the fruit set from 33.7% to 88.75% and takes 7-8 months to mature. The fruit may be harvested from the tree after splitting, but it may also be gathered after is removed from the scarlet aril in split fruits. Later the mace is taken off and is dried separately from the nutmeg in its shell.

The proportion of dried shelled nutmegs to dried mace is approximately 20:3. During drying, nutmegs loose about 25% of their weight. The average yield of a good tree in full bearing is about 1500 to 2000 fruits per annum. On government Research Station in Grenada the average yield was recorded 2800 kg/ha of green nuts after about 14 years, which is equivalent to 1000 kg/ha of dry nuts Purseglove *et al.,* (*1981).* The yield may vary between 560 to 1120 kg/ha and 84 to 168 kg/ha of mace per annum. A large tree yields 3000-10,000 fruits annually (Shanmugavelu and Madhava Rao,1977). Being composed of thin lacy material, the mace is very light and consequently, for every 100 kg of nutmeg a tree produces, it yields only 3.5kg of mace, Pruthi (1979).

2.6 Grades of nutmeg and mace

The dried nutmegs are graded by hand according to weight, shape, color. After grading, nutmegs are fumigated with methyl bromide before being bagged and shipped in order to protect the nutmegs from storage pests. The following classification has been adopted in the nutmeg grade, (Pruthi,1979) .

1. **Whole and sound nutmeg:** This is used in spice trade viz:

   (a) Large seed.

   (b) Medium seed.

   (c) Small seed.

2. **Sound Srivels:** These are employed for grinding but are usually too expensive for oil distillation.

3. **Rejections:** Considerably lower priced, this grade can be used for oil distillation.

4. **Broken and warmy:** This is the cheapest grade, large quantities of which have been shipped to Europe, especially to Hamburg for oil distillation. This

quality grade comprises all broken and loosened up nutmegs which seem to contain much less fatty oil than the sound nuts. For this reason, it is very suitable for distilling, (Pruthi, 1980).

Commercial mace consists of flattened lobbed pieces, 2-5cm or more in length, some what less in breadth and 1mm thick. It is dull yellowish red in color translucent and brittle. In odour and taste, it resembles nutmeg, but is softer and more delicate. The types of mace recognized in trade are Banda Mace, Java Estate and Saww Mace, (John and Krishnamurthy, 1992).

2.7 Physical properties of Nutmeg mace

The study of the physical properties of nutmeg mace is essential for the design of the equipments for handling and processing. To select an appropriate method for the determination of various properties of nutmeg mace, literature on other similar agricultural materials was reviewed since not much work was done for nutmeg mace.

2.7.1 Moisture content

Moisture content was determined by toluene distillation method using Dean Stark apparatus as per Associates of Official Analytical Chemists (AOAC, 1975) method. The method is explained in section. 3.2.1. The average moisture content of nutmeg mace was reported as 65% (wb), (John and Krishnamurthy, 1992).

2.7.2 Bulk Density

The bulk density of nutmeg was reported as 488 kg m^{-3}, Thomson and Isaac (1967).

2.7.3 True Density

The true density was measured using the values of unit volume and unit mass of individual seeds. The true density of nutmeg was reported as 830.54 kg m^{-3}, Thomson and Isaac (1967).

2.7.4 Porosity

The porosity was calculated from average values of bulk density true density. The porosity of nutmeg was reported as 41.10%, Thomson and Isaac (1967).

2.8 Production of Dried Mace

2.8.1 Sun Drying

John. *et.al.,* 2004, reported mace is 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 color of the dried mace. The dried mace so obtained does not posses uniform red color. Also about 2-3% of the mace gets charred in the process. Sun drying bleaches the color and contaminates mace with mold growth ending in poor appearance. Hence sun drying is not an ideal practice.

2.8.2 Smoke Drying

Pruthi (1970) 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 posses good appearance and there is loss of volatile oil content.

Gopalakrishna *et al.,*1980, reported that hot air drying is a viable technology for curing mace. Mild blanching with 75ºC for 2 min and subsequent drying of mace at 50ºC in a cross flow dryer helped in retention of color and general quality of mace.

Nair.1994, reported that drying of mace was carried out in the Agricultural Waste fired Dryer. 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 posses good appearance and there is no loss of volatile oil content.

Thomas and Paulose. 2001, reported a RRLT-NC dryer for drying spices. This could be effectively used for drying nutmeg mace. In this dryer hot air is generated by appropriate means is made to rise through a separated duct and is made to enter into the drying chamber at the top. In the drying chamber except the bottom all the sides are closed and is air tight. Perforated trays (for keeping wet material to be dried) are placed in the drying chamber. Hot air after entering into the chamber when get contacted with the material to be dried gets partially cooled and has a tendency to flow down relatively. The reverse flow of hot air is accomplished without the help of any blower or fan. Based upon the capacity requirements and mode of heating different models are developed. Hot air needed form the drying is generated by burning Coconut shell, Husk, Fire wood etc. The temperature of the air in the drying chamber at different points was monitored using thermocouple temperature sensors. The air temperature was maintained between 50 to 60^0 C by regulating the rate of burning of fuel. The rate of firing was adjusted by regulating the air in flow control valve to the furnace and the butterfly valve provide in the smoke and flue gas exit pipe from the furnace.

2.9 Quality requirement of Nutmeg mace

Nutmeg and mace are widely used as condiments and in medicine. It is evaluated for its appearance (color), pungency and its aroma or flavor properties. The aroma is contributed by its essential oil, which consists of a wide variety of chemical constituents viz. Myristicin, Elemicin and Safrole etc.

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

Gas chromatographic analysis of nutmeg and mace oils by (Gopalakrishnan, 1992) showed that β-pinine and Sabinine together constituted 77.38% and 60.76% in nutmeg and mace oil respectively and also noted that the concentration of Myristicin and Elemicin are very high in Indian oils(oils from nutmeg cultivated in India).

Mallavapuram and Ramesh. 1998, reported that nutmeg oil contained 76.8% monoterpenes,12.1% oxygenated monoterpenes and 9.8% phenyal propanoid ether. He also reported that mace oil consisted of 51.2% monoterpens, 12.1% oxygenated monoterpens, 30.3% oxygenated monoterpens and 18.8% phenyl propanoid ether. The oleoresin or the solvent extract represents the total pungency and flavor of Nutmeg mace.

2.9.1 Mace oil

Clevenger. 1952, reported that yield of oil is about 4-17% as a colorless 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 the air.

Shulgin *et al.,* 1967, reported that the aromatic ether content of the mace oils ranged from about 8-18%, and in all cases Myristicin was found to be the major constituent, with smaller amounts of Safrole and Elemicin. The East Indian mace oil analyzed by Forrest and Heacock (1972) contained 87.5% monoterpenes, 5.5% monoterpene alcohols and 6.5% aromatic ethers.

Salzer.1975, reported that the gas chromatograph of the steam-volatile oil distilled from a mace oleoresin and he noted that the Myristicin content of this oil was greater than that of commercial nutmeg oil.

Salzer.1975, reported the main difference noted in the content of aromatic ethers was more in the cured mace oils than in the nutmeg oils. Also, a taste panel could detect differences in the flavor between the nutmeg and cured mace oils obtained from the same tree and this finding provides further support to the view that the aromatic ethers play a central role in determining the organoleptic character of nutmeg and mace oils and also its contrast with East Indian nutmeg (Indian) and mace oils, in which Myristicin is the most abundant component in the aromatic fractions.

Dann *et al.,* 1977, showed the general composition of the cured mace oils was 75-94% monoterpene hydrocarbons, 7-17.6% oxygenated monoterpens and sesquiterpenes and 0.5-9% aromatic ether.

Dorman and Deans. 2000, reported that numerous *in vitro* studies have demonstrated the effectiveness of nutmeg and oregano against food-borne pathogens.

So far, little information is known about the inhibitory effect of essential oils of oregano and nutmeg against specific food-borne pathogens in food.

Tainter and Grenis. 2001, reported that main chemical components of nutmeg oil are Borneol, Geraniol, Linalool, Terpineol, Eugenol, Myristicin, Safrole, Camphene, Dipentene and Pinene.

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

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.

2.9.2 Myristicin and 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 flavoring processed foods since they have grater 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.

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

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

Gopalakrishna.1992, reported that the Myristicin is the main orgenoleptic component in the mace oil. It gives the true aroma and flavor 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 methyoxy Safrole, the principal aromatic constituent of nutmeg and mace oil. In human beings, 6-7mg kg^{-1} of body weight is enough to cause psychopharmacological effects. Ingestion of 5g nutmeg mace corresponding to 1-2mg Myristicin kg^{-1} body weight has been shown to cause intoxication.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The various methods adopted in the determination of physical and chemical properties of Nutmeg Mace relevant to the study, the development and evaluation of a convective dryer for nutmeg mace and analyses of the quality of the dried nutmeg mace are dealt in this chapter.

3.1 Test sample

Nutmeg Mace (***Myristica fragrans Houtt***.) harvested in June-July, 2007 procured from the farmer of the Tavanur was used for the study.

3.2 Moisture content

The moisture content of the mace was determined for the raw material as well as during the drying studies.

3.2.1 Determination of moisture content of Mace

Moisture content was determined by toluene distillation method using Dean Stark apparatus as per Association of Official Analytical Chemists (AOAC, 1975) method. Toluene, measuring 100 ml, was taken in a distillation flask containing 5 g of ground Mace sample. The flask was attached to the Dean Stark apparatus with the condenser (Plate 3.1). On boiling, the water vapor along with toluene got distilled from the flask, condensed, and was trapped in the receiver of the apparatus, which contained toluene. Distillation was continued until the volume of moisture collected remained constant. The apparatus was cooled at room temperature and weight of moisture collected was noted. The moisture content was calculated by,

$$\text{M.C. (w.b), \%} = \frac{W_w}{W} \times 100 \quad \text{---- (3.1)}$$

where,

W_w = Weight of water collected, g

W = Intial weight of sample, g

M.C (w.b) = Moisture content, % wet basis

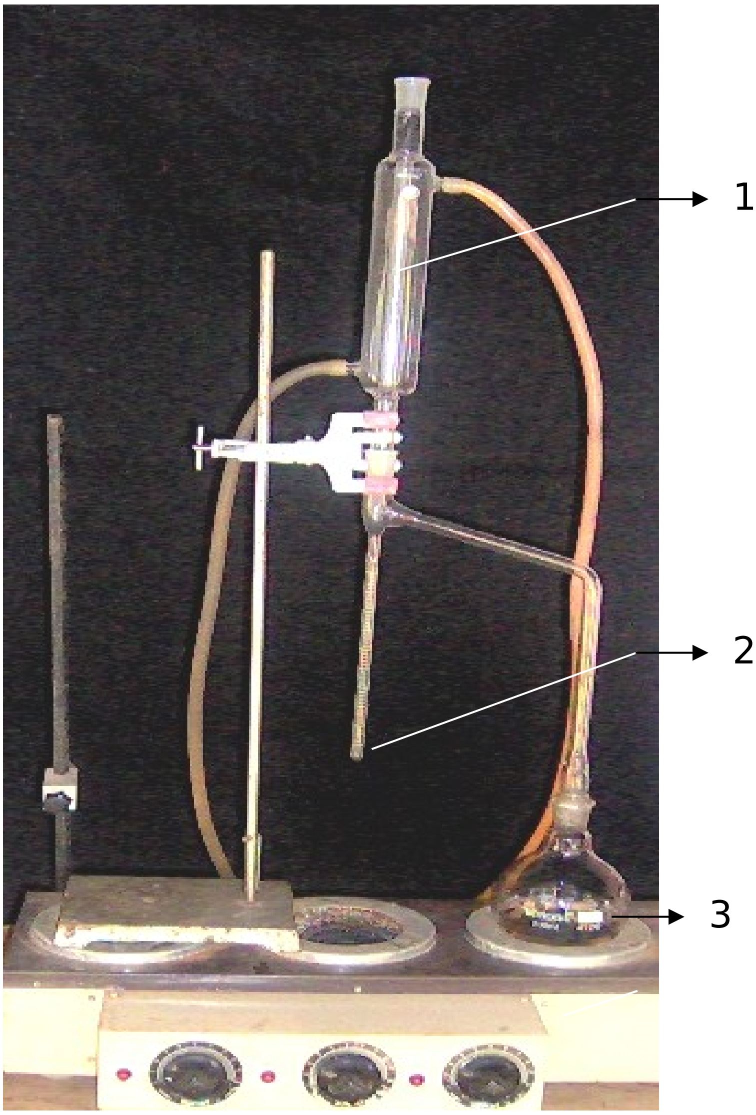

Plate 3.1 Dean Stark Apparatus

1. **Condenser**
2. **Dean Stark Apparatus (moisture collected)**
3. **Round Bottom Flask (Sample + Toluene)**

3.3 Development of a convective type dryer for nutmeg mace

To offset the problem involved in conventional drying of nutmeg mace, a convective type dryer was developed. The developed dryer consists of the following components.

1. Drying chamber.
2. Plenum chamber
3. Heating coil box.
4. Air flow control.
5. Blower with Power source.

3.3.1 Drying chamber

The drying chamber is fabricated using18 gauge GI sheet cut and rolled to form a cylindrical tube with diameter 20 cm and height 70 cm. The diameter and height was taken as 20 cm and 70 cm, respectively in order to maintain high velocity and to obtain better fluidization. Perforated steel plate of 20 cm diameter with holes of 0.5 mm diameter was welded to the bottom of the cylinder which forms the floor of the drying chamber. The center to center distance between holes 1 cm. Hot air from the plenum chamber is blown through these holes to the bed of the nutmeg mace resulting in fluidization. An asbestos rope of diameter 2 cm was wound around cylindrical drying chamber up to 30 cm height to minimize the heat loss. An inspection GI door of dimension 15×20 cm was also provided at height of 25 cm from the bottom with arrangement for proper locking.

3.3.2 Plenum chamber

The plenum chamber is also constructed using 18 gauge GI sheet formed into a conical shape with top having diameter 20 cm welded to the bottom having of the drying chamber and bottom diameter 10 cm connected to the hot air GI pipe extending from the heating coil box. The plenum chamber was wound with 2 cm diameter asbestos rope to reduce heat loss to surroundings.

3.3.3 Heating coil Box

The heating coil box was made using 18 gauge GI sheets to form a rectangular box of dimensions 25×11×10 cm. The inside of the box is provided with asbestos sheet 10 mm thick on all sides in order prevent heat losses. Two heating coils of 2000 watts capacity was fixed at the bottom of inside portion of the box and is connected to 230 V,50 Hz electric power supply through a switch board. The connections are such that the each heating coil is independent and can be switched ON or OFF individually depending upon the heating requirement. The forward end of the box was connected to the plenum chamber via a 10 cm GI bend and coupling and opposite end to a blower through a 5cm diameter, 60 cm length GI pipe and control valve. The entire surface of the pipe from box outlet to plenum chamber was wound with 2cm diameter asbestos rope to minimize heat loss.

3.3.4 Air flow control

In order to control the flow rate of the air and thus to maintain fluidization in the drying chamber, a ball flow control valve made up of brass was employed. The diameter of the valve is 3 cm. This was fitted in between the blower and heating coil box and therefore the amount and velocity of intake air for heating can be controlled by turning the valve handle.

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3.3.5 Blower with Power Source

A 2800 rpm centrifugal blower with 1hp motor was used as the source of air which is heated and then supplied to the drying chamber for drying and fluidization. The entire set up is kept at a height of 13 cm from the ground level by means of angle iron stand.

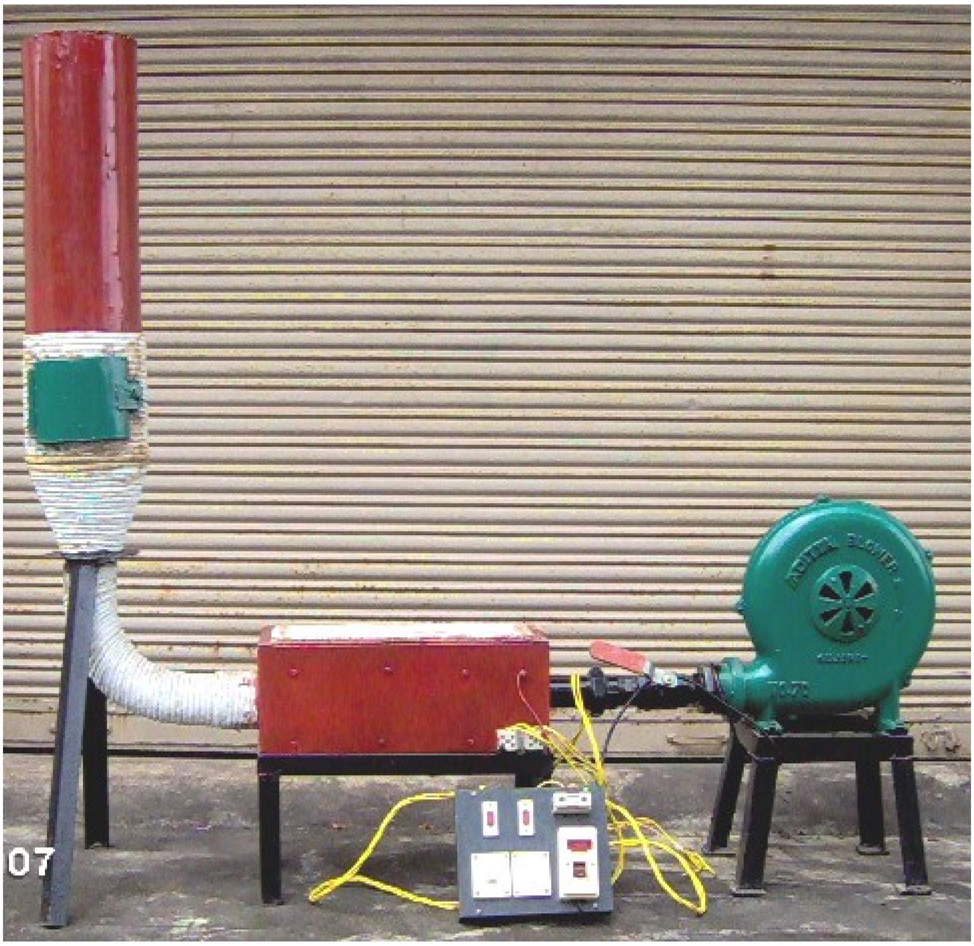

Plate 3.2 Nutmeg mace dryer- Front view

Plate 3.3 Nutmeg mace dryer- Side view

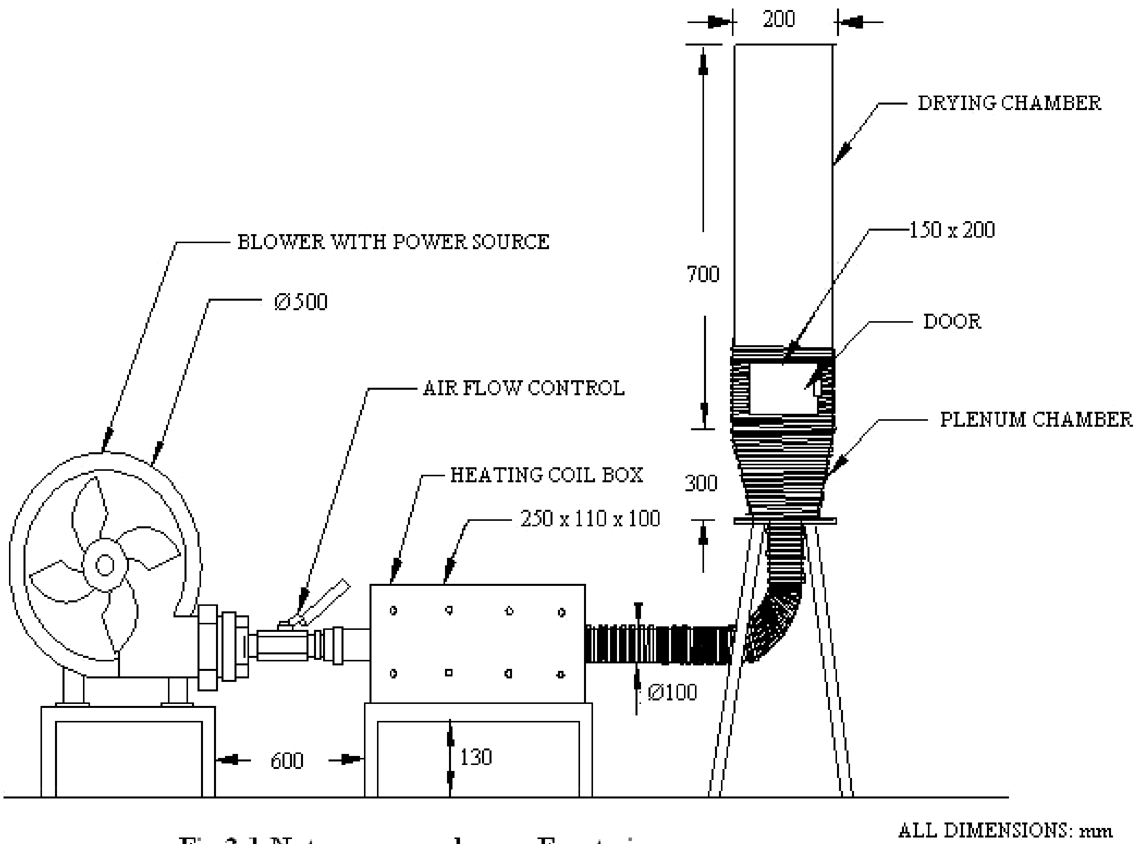

Fig 3.1 Nutmeg mace dryer - Front view

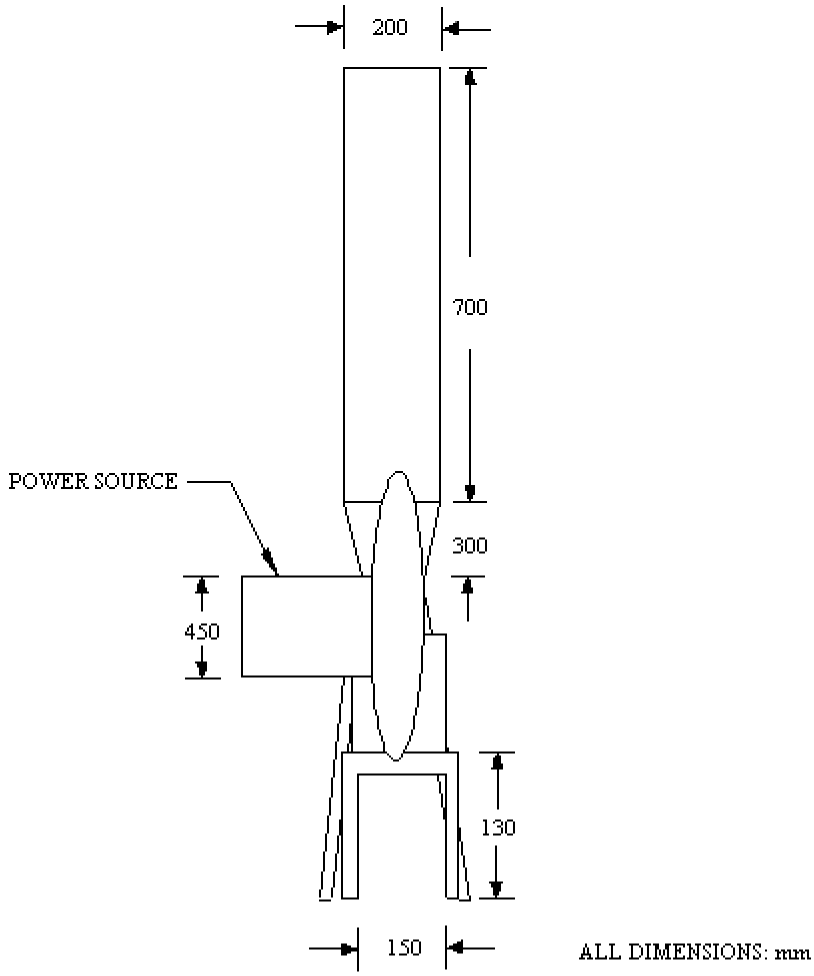

Fig 3.2 Nutmeg mace dryer - Side view

3.4 Sun drying of samples

In order to compare the effectiveness of the drying process of nutmeg mace by the developed dryer over the conventional method, sun drying was carried out for mace samples procured from the farm. 50 g of sample was spread on a stainless steel tray and was kept under the sun during day time. Since the harvesting season is during active monsoon proper watch is essential to remove the mace to shelter as and when it rains and during night. The total drying time was noted for the three such samples kept as control and final moisture content was also determined. The quality analysis of these samples was also carried out on the quality parameters set for the study.

3.5 Experimental Design

The experiment was conducted as a 2-factor experiment in Completely Randomized Design (CRD). The variables set for study and the levels of treatments were given below. For each experiment the number of replication were three.

I Independent Variables	**Levels of treatment**		
Drying air Temperature (°C)	40,	45,	50
Air Velocity (m/s)	1.6,	2.0,	2.4.
Weight of the product in the dryer (g)	100,	100,	100.

II Dependent Variables

Machine parameters

(i) Drying Time (hr).

(ii) Power requirement(kW).

(iii) Thermal efficiency (%)

Product parameter

(i) Volatile oil content (%db).

(ii) Oleoresin content (%db).

(iii) Myristicin content (ml)

(iv) Color.

Accordingly, the total numbers of experiments were 3×3×2=18.

A thorough review of literature reveals that blanching of mace by dipping in hot water at temperature of 75 ^{0}C for 2 min prior to drying gave better appearance and high volatile oil content (John Zachariah *et al*., 2004) . Therefore blanching was also carried out by keeping the mace in cotton cloth and dipping in hot water at 75 ^{0}C for 2 min for such set of treatments that gave better results in the study. The quality analysis of such samples was also carried out.

3.6 Experimental procedure

Freshly harvested mace procured from local farmer was used for conducting the studies. The initial moisture content was determined by AOAC (1975) method. The sample a weight of 100 g of mace was weighed in electronic balance was used for evaluation. The blower was started and the heating coils were switched on. The temperature of the heated air was varied by switch on one or both the coils as per the requirement. The air velocity was varied by air flow control valve. Once the temperature reaches the required level, the sample was loaded in the drying chamber. As drying proceeds, at every 30 min interval, moisture content was determined.

3.7 Performance evaluation of Nutmeg mace dryer

The nutmeg mace dryer was evaluated for its performance at various drying air temperature and velocity. The drying air temperature was varied by switching on the heater coils as per the requirement and also by varying the air flow rate. The air velocity was varied by turning the handle of the flow valve. For each set of variations the dependent variable set for the study were found

3.7.1 Drying time

The initial moisture content of a 100 g fresh mace sample was determined by AOAC method after a sample was kept in the drying chamber. The initial moisture content was 65% (wb). After every 30 min intervals the moisture content of the dried mace sample was determined by using AOAC method. According to US standards moisture content of the mace was not more than 6% (wb) (Purseglove *et al*., 1981). The drying of the mace was carried out to reduce the initial moisture content 65% (wb) to 6% (wb) final moisture content. After reaching the final moisture content the drying time was noted down.

3.7.3 Energy requirement

The energy requirement for loaded condition was determined using an energy meter. A three phase energy meter was connected in series with motor. Then the energy consumed for the total drying time was calculated.

3.7.4 Thermal efficiency

The thermal efficiency of the developed dryer was calculated based on an ambient temperature (T1), Heated air temperature (T2) and Exhaust air temperature (T3) by using following equation.

$$\eta = \frac{\text{Air temperature decreases during drying } (T2 - T3)}{\text{Air temperature increses during drying } (T2 - T1)} \quad \text{-------------} \; 3.11$$

(Ref : Chakraverty, A. 2007)

3.8 Quality analyses of mace

The nutmeg mace dried in the developed dryer is subjected to subsequent quality analyses. The important product factors analyzed were Volatile oil, Oleoresin content, Myristicin content and Color.

3.8.1 Volatile oil

The volatile oil content of the dried mace was determined by distillation method using Clevenger apparatus as shown in Plate 3.6.

A 100g of dried mace powder and 500ml of distilled water were taken in a round bottom flask and 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 65 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 3 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 (g) per unit mass of sample.

$$\text{Volatile oil, \% (v/w)} = \frac{V}{W} \times 100 \qquad \text{---- (3.12)}$$

where,

V = volume of oil collected ml, assumed g

W = Total weight of the sample, g

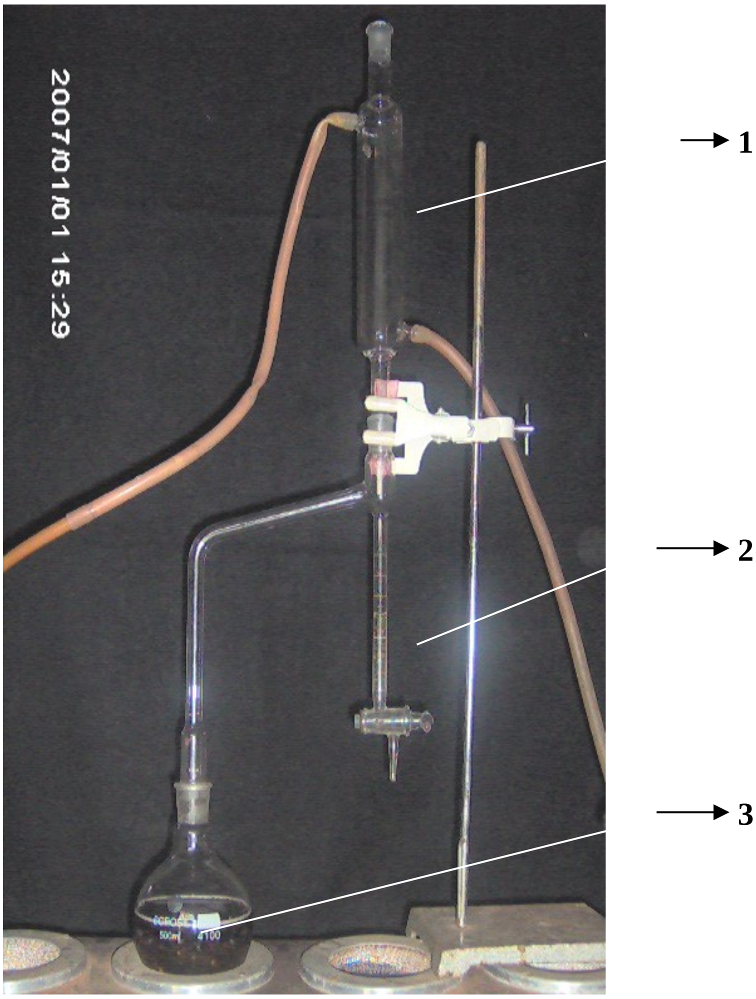

Plate 3.4 Clevenger apparatus

1. **Condenser**
2. **Clevenger Apparatus (oil collected)**
3. **Round Bottom Flask (Sample + Distilled water)**

3.8.2 Oleoresin content

The oleoresin was extracted with n-hexane by employing a solvent extraction method using a Soxhlet extraction apparatus (Plate 3.5).

Mace powder of 25 g was packed in a thimble and kept in the extraction tube of the Soxhlet apparatus. About 75 ml of n-hexane was taken in the Soxhlet flask and attached to the extraction tube along with a condenser. The Extraction was continued for four hours (six cycles) on water bath. At the end of the extraction period, the mace powder packet was removed from the apparatus and distilled further for the removal of the solvent. The last traces of the solvent were removed at room temperature using a vacuum pump.

$$\text{Oleoresin, \%} = \frac{\text{Weight of extracted oleoresin}}{\text{Initial Weight of mace powder}} \times 100 \qquad \text{---- (3.13)}$$

3.8.3 Myristicin content

The major volatile oil aroma component in the mace oil is myristicin, therefore the quantification of myristicin content may be taken as a parameter for assessing the quality of mace. The volatile components of mace were extracted using Clevenger apparatus (Plate 3.4) and analyzed by Gas chromatograph (Plate 3.6). The model GC–Shimadzu-17A equipped with Flame Ionization Detector (FID) was used. The mace oil of 0.5 µl was injected under the following conditions.

Column	: DB-1
Type of column	: Capillary
Column temperature	: 70 to 225^{0}C at the rate of 5^{0}C/ min
Detector temperature	: 275^{0}C
Injector temperature	: 250^{0}C
Nitrogen flow	: 11 µ l/min.

Concentration and quantification of myristicin was carried out using the reference standards obtained from m/s Sigma Chemical Company, Unite States of America (U.S.A.). The peak obtained by injecting standard and the samples were analyzed and the quantification of myristicin was carried out.

3.8.4 Color

The color of dried mace was observed by colorimeter (Plate 3.7). The hunter lab Colorimeter was used for color measurement.

Type : Mini scan XE plus spectrocolorimeter

Name : Hunter lab colorimeter

Model: 4000S

Geometry : 45°/ 0°

Viewing area: Smaller area view

$$\Delta E = \sqrt{(\Delta L)2 + (\Delta A)2 + (\Delta B)2} \quad \text{----------------} \ (3.14)$$

ΔE =Total color difference

$\Delta L = L - Lo,$ $\Delta A = A - Ao$ and $\Delta B = B - Bo$

L,A,B = Measured values of dried sample

Lo, Ao,Bo= Values of standard mace sample

(Ref –Miniscan XE plus users guide, Hunter lab colorimeter)

The dried mace samples were then kept in the instrument port as per the instruction provided in the literature and then readings were noted.

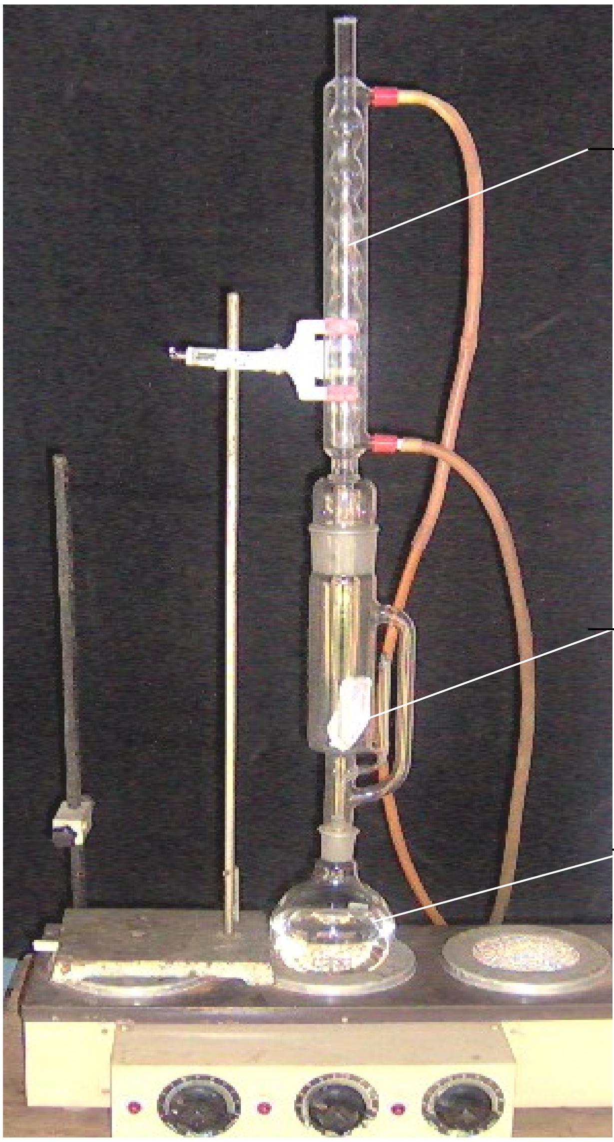

Plate 3.5 Soxhlet apparatus

1. **Condenser**
2. **Soxhlet Apparatus (Sample)**
3. **Round Bottom Flask (n-hexane)**

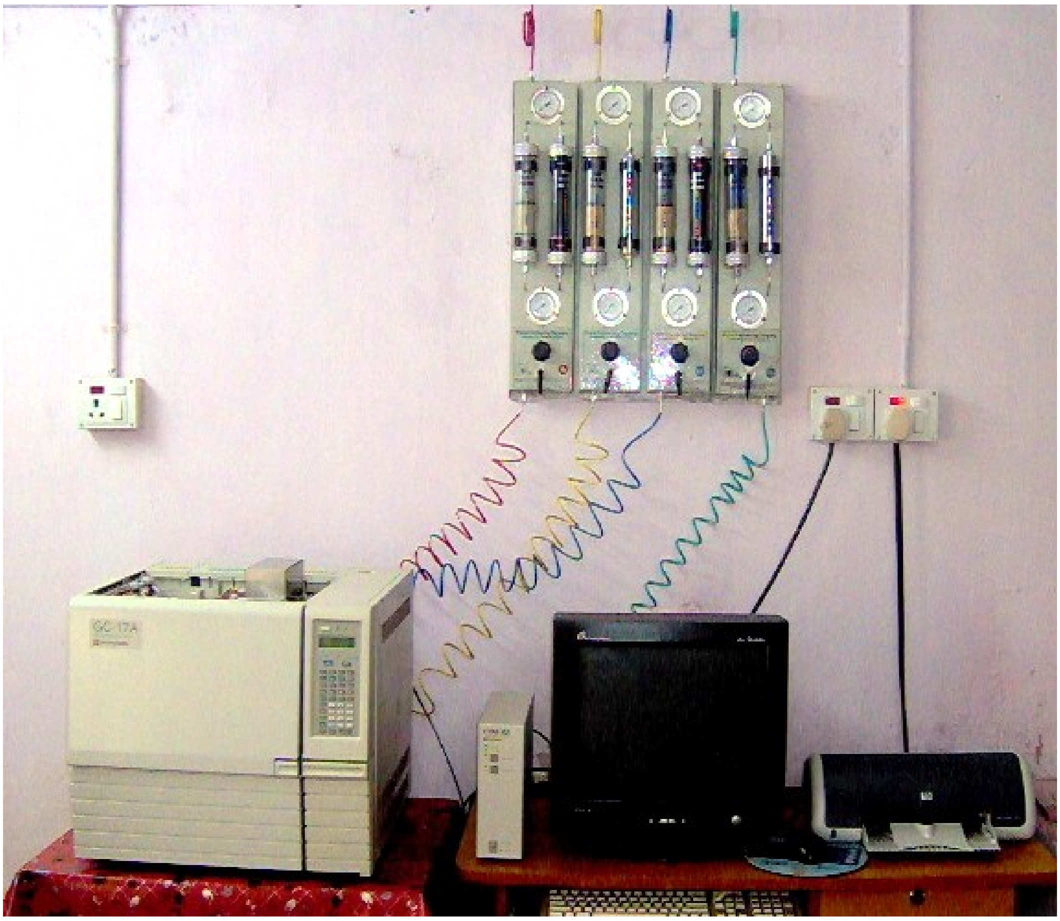

Plate 3.6 Gas chromatograph

Plate 3.7 Colorimeter

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, results of the experiments conducted to evaluate the nutmeg mace dryer and evaluation of quality of the dried mace are presented and discussed.

4.1 Development of a convective type dryer

A convective type dryer with air heating and provision for controlling air flow was developed with drying chamber, plenum chamber, heating coil box, air flow control and blower with power source as prime components. The performance evaluation of the developed dryer was carried out and compared with conventional sun drying.

4.2 Moisture content

The initial moisture content of the fresh mace was found to have a mean value of 63.87% (wb) with values ranging from 62.5 to 65.5%.

4.3 Performance evaluation of the nutmeg mace dryer

Performance of the developed dryer was evaluated and the results are discussed below. The dryer was tested by varying the drying air temperature and air velocity.

Effect of different drying air temperature and air velocity on quality parameters like volatile oil, oleoresin, myristicin, color and machine parameters such as drying time and energy requirement were determined by conducting a 2 factorial experiment using completely randomized design (CRD). The effect of the two parameters ie drying air temperature and air velocity were analyzed and results of the experiments (Table –ANOVA) are presented.

4.3.1 Effect of different drying air temperature and air velocity on drying time and moisture content

The drying curve of the nutmeg mace at different drying air velocities were plotted for different temperature ranges Viz. 40 ºC, 45 ºC and 50 ºC and is shown in fig 4.1, 4.2 and 4.3 respectively. Drying continued until the moisture content reached 6% (wb) as the moisture content of dried mace should not be higher than 6% (wb) as per EOA specification.

It may be seen from the drying curves that at a temperature range of 40 ºC for different air velocities, the moisture loss was high at initial stages of drying and after about 3 hrs, of drying the drying curve levels off and reaches constant value. The total drying time was 4.5 hrs in this case.

Also at temperature range of 45 ºC, for different air velocities a similar trend was observed as in the case of 40 ºC range. But the total drying time from initial to final moisture content of 6% (wb) got reduced to 3.5 hrs.

At temperature range of 50 ºC, for different air velocities the rate of moisture removal was high in the initial stages and then shows down and becomes constant. The total drying time in this case was also 3.5 hrs.

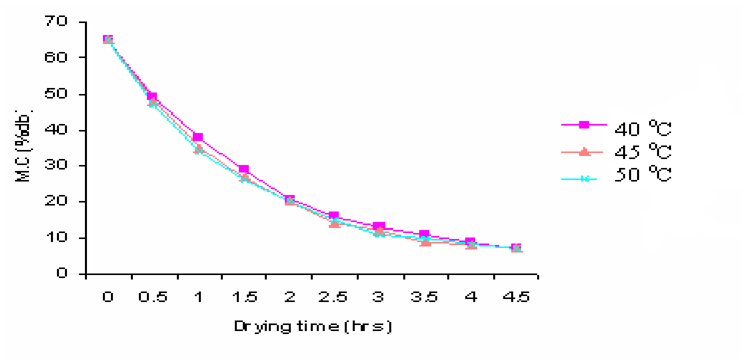

Fig 4.1 Variation of moisture content with time of drying at a temperature range of 40 ºC

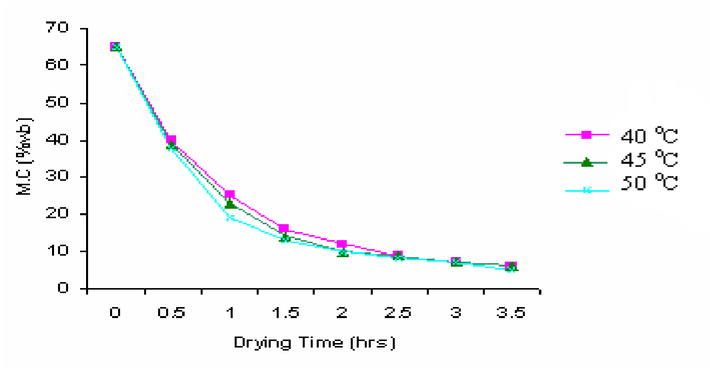

Fig 4.2 Variation of moisture content with time of drying at a temperature range of 45 ºC.

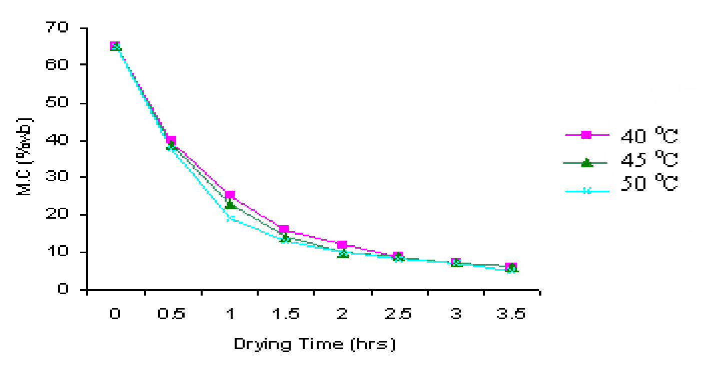

Fig 4.3 Variation of moisture content with time of drying at a temperature range of 50 ºC.

4.3.2 Effect of different drying air temperature and air velocity on volatile oil content

From the analysis of variance (ANOVA) it is evident that drying air temperature and air velocity has significant influence on volatile oil content at 5% level of significance.

The volatile oil extraction percentage on dry basis at different drying temperature and air velocity is presented in Table 4.1. It may be seen that the average volatile oil percentage at 1.6m/s air velocity at three different drying temperature is 10.66%(db). Also at temperature range of 40 ºC at different air velocities, average volatile oil extraction is 10.39% (db). The average oil extraction percentage at 2.0 m/s for three different drying temperatures is 10.99% (db) and also at temperature range of 45 ºC for different air velocities average oil extraction is 12.33% (db). The average oil extraction percentage at 2.4 m/s at three different drying temperatures is 11.33% (db) and also at temperature 50ºC at different air velocities average oil extraction is 10.27 % (db). It was observed that the volatile oil extraction percentage was maximum at drying air temperature of 45 ºC at an air velocity 2.4m/s.

Fig 4.4 shows the variation of volatile oil content for different heated air velocity and temperature range. It was observed that at 40 ºC range, the volatile oil content initially increases from 1.6 m/s to 2.0 m/s and then showing a decreasing trend as the velocity of air increased. Where as for 45 ºC range the volatile oil content is showing an increasing trend as the velocity of heated air increased. For 50 ºC range, the volatile oil content increased marginally and then became constant with increase in air velocity. The maximum value of oil content obtained was 13.5 which was observed at air velocity of 2.4m/s for an air temperature range of 45 ºC Similar trend was also observed in John *et.al.* 2004, for nutmeg.

Table 4.1 : Volatile oil content (%db) of the dried mace sample

Temp (^oC)	Air velocity (m/s)			Mean
	1.6	2.0	2.4	
40	10.33	10.66	10.16	10.39
45	11.5	12.0	13.5	12.33
50	10.16	10.33	10.33	10.27
Mean	10.66	10.99	11.33	

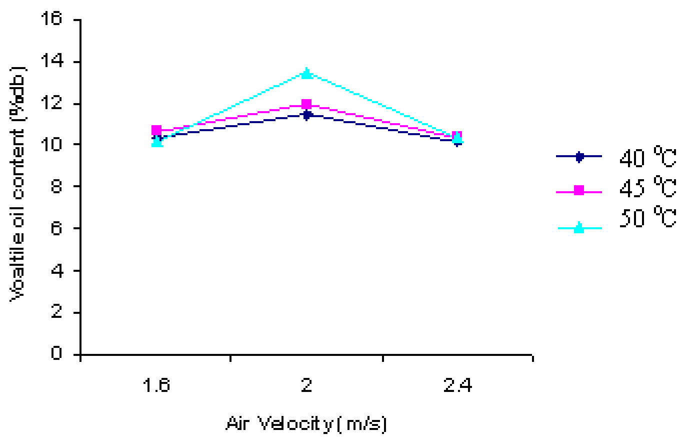

Fig 4.4 Effect of different air velocity and different temperature on volatile oil content

4.3.3. Effect of different drying air temperature and air velocity on oleoresin content

From the analysis of variance (ANOVA) it is evident that air velocity and temperature range has significant influence on oleoresin content at 5% level of significance.

Table 4.2 shows the oleoresin content extraction percentage on dry basis at different drying air temperature and air velocity. The average percent oleoresin content at 1.6m/s air velocity at three different drying air temperature was 19.28 %(db). Also at temperature range of 40 ºC, for different air velocities average oleoresin content was 19.22 % (db). The average percent oleoresin content at 2.0 m/s air velocity at three different drying temperatures was 19.27% (db) and also at temperature range of 45 ºC at different air velocities average oleoresin extraction was 19.27 % (db). The average oleoresin content extraction percentage at 2.4m/s at three different drying temperatures was 19.93 % (db) and also at temperature range of 50 ºC for different air velocities average oleoresin extraction was 19.34 % (db).

It was found that in oleoresin extraction percentage the maximum extraction was observed for drying air temperature of 40 ºC at 1.6 m/s. The trends are also presented in Fig 4.5. (John Zachariah *et.al.* 2004).

Table 4.2 : Oleoresin content (%db) of the dried mace sample

Temp (^{O} C)	Air velocity (m/s)			Mean
	1.6	2.0	2.4	
40	22.13	20.16	19.5	19.22
45	18.36	18.33	18.16	19.27
50	20.0	19.55	19.16	19.34
Mean	19.28	19.27	19.93	

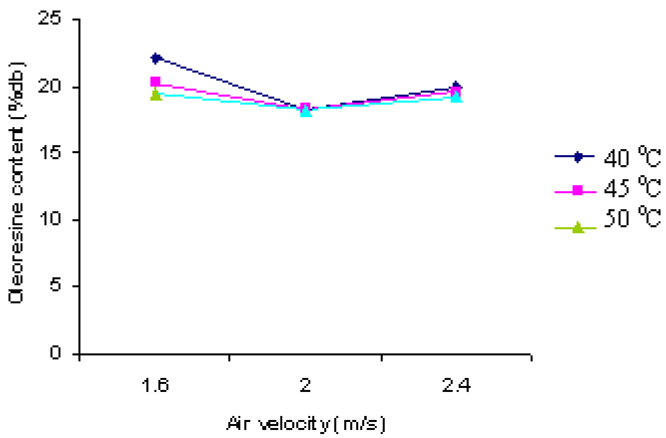

Fig 4.5 Effect of different air velocity and different temperature on oleoresin content

4.3.4. Effect of different drying air temperature and air velocity on color

The color of the dried mace samples measured using colorimeter at three different air temperatures and three different air velocities are presented in table 4.4. The color difference for each treatment was computed based on the formula as given in section 3.8.4 and the variation is plotted in Fig 4.6. It was observed that at a heated air temperature range of 40 ºC for the three different air velocities the total color difference was 18.31. Similarly for 45 ºC range and 50 ºC range the color difference observed for different air velocities were 16.91 and 20.64 respectively. A minimum value of total color difference gave good color of dried mace. Accordingly it was observed that the drying air temperature of 45 ºC produces the minimum total color difference and hence has the best color compared all other treatments.

4.3.5. Effect of different drying air temperature and air velocity on myristicin Content

The myristicin content of the dried mace samples measured using Gas Chromatograph at three different air velocities and three different temperatures are presented in table 4.4. The myristicin content difference for which gave minimum values were treatment computed based on the peak values of the standard and that of the samples, from the graph plotted from the Gas Chromatograph are shown in the fig 4.10. It was observed that at a heated air temperature range 40 ºC for the three different air velocities the average myristicin content was about 1.803. Similarly for 45 ºC and 50 ºC range for the different air velocities the average myristicin content were 2.418 and 1.499 respectively. It may be reveled from the table and figures that the drying air temperature range of 45 ^{0}C and air velocity 2.4 m/s gave maximum myristicin content of 2.478.

Table 4.3 Color of the dried mace sample at different temperature

	D_l	Da	D_b
Temp (^{O} C)	17.26	21.36	11.60
40 ^{0}C	14.43	3.45	8.98
45 ^{0}C	15.31	4.81	8.67
50 ^{0}C	11.34	2.02	7.34

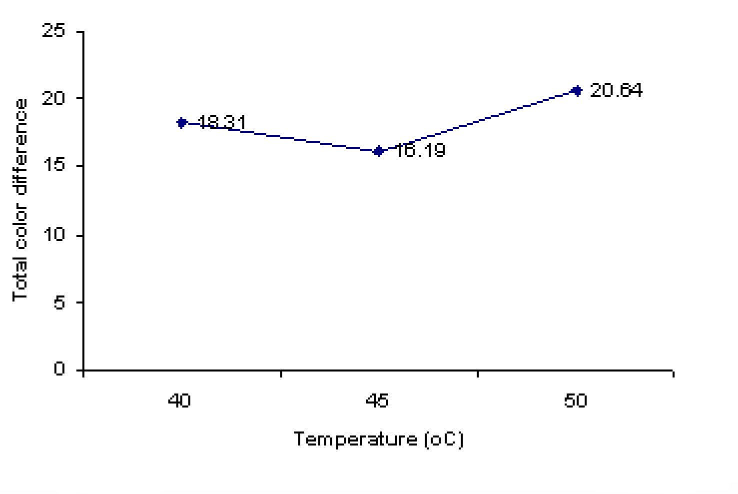

Fig 4.6 Total color difference at different temperature

Table 4.4 : Myristicin content (ml) of the dried mace sample

Temp (^{O}C)	Air Velocity (m/s)			Mean
	1.6	2.0	2.4	
40	1.865	1.768	1.778	1.803
45	2.380	2.397	2.478	2.418
50	1.564	1.478	1.456	1.499
Mean	1.936	1.881	1.904	

4.3.6 Energy requirement

The energy consumption kWh for drying the mace to the final moisture content of 6% (Wb) at different air temperature and air velocity are shown in table 4.7.

It may be reveled from the table that the minimum energy consumption of 1.9 kWh was observed for temperature range 45 ^{o}C and at air velocity of 2.4 m/s and the maximum energy consumption of 3.0kwh for temperature range of 40 ^{o}C and air velocity of 2.0 m/s.

From the results of the studies conducted to evaluate the performance of the developed dryer it was observed that at a heated air temperature range of 45 ^{o}C and at an air velocity of 2.4m/s, the dryer parameters quality parameters were found to be superior to other treatments. The drying time was only 3.5hrs to reduce the moisture content from initial value to 6% (wb). The volatile oil content and myristicin content percentage were also found to be higher with values of 13.5% and 2.478% respectively at 45 ^{o}C, 2.4 m/s combination of drying air temperature and drying air velocity. It may be noted that this combination yielded maximum essential oil which is more important and can be justified for a comparatively low oleoresin yield. Also the color difference was found to be minimum which indicates that the sample dried at this treatment combination is superior to other combination. The energy consumption was also found to be minimum with a value of 1.9 kWh.

From the results it may be concluded that a drying air temperature range of 45 ^{0}C and air velocity of 2.4 m/s may be considered optimum in terms of drying efficiency, drying time, energy consumption and product quality parameters such as Volatile oil content, oleoresin content, myristicin content and color. This optimum combination was then used for further comparison studies.

Table 4.5 Energy consumption at different air velocity and different drying air temperature

Air velocity (m/s)	Energy consumption (kWh)		
	Drying air temperature (^oC)		
	40	45	50
1.6	3.0(5.5)	2.1(4.5)	2.4(3.5)
2.0	2.8(5)	2.0 (4)	2.2(3.5)
2.4	2.5(5)	1.9(3.5)	2.2(3)

Table 4.6 Quality parameters of mace at different drying methods

Sample	Volatile oil% (db)	Oleoresin %(db)	Myristicin content	Color difference
A	9	28	1.582	23
B	12.33	19.21	2.478	16.91
C	12.90	18.98	2.480	15.57

4.3 Thermal efficiency

It may be reveled from the fig 4.7 that the higher thermal efficiency of 69% was observed for temperature at 45 ºC and the minimum thermal efficiency of 50% for temperature at 40 ºC.

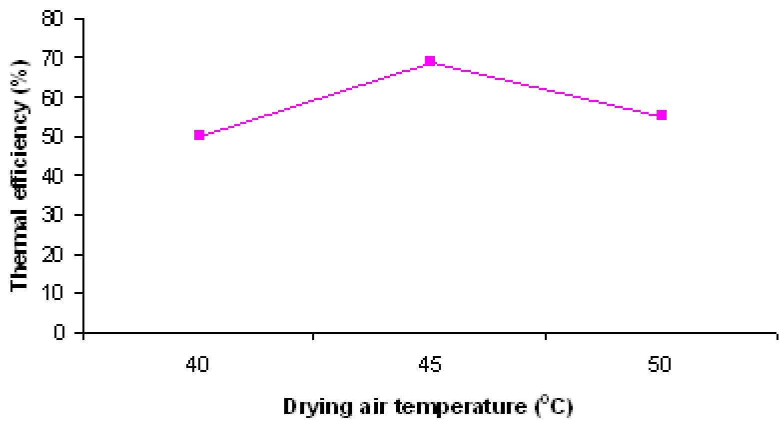

Fig 4.7 Thermal efficiency of the dryer at different drying air temperature

4.4 Comparison between dried mace obtained by developed dryer and sun drying method

Plates A-C depicts mace samples dried by the three methods such as conventional method (sun drying), developed dryer and developed dryer with blanched samples. From the plates it may be observed that the mace dried by developed drier and that with developed drier with blanched samples show better appearance than sun dried sample. Mold growth was also observed in samples dried under sun. A drying air temperature range of 45 ºC and air velocity of 2.4m/s were used for analysis.

The results of test conducted to determine the volatile oil content, oleoresin content, myristicin content and color are given in table 4.8. Where

A=Sun dried sample

B=Developed dryer unblanched dried mace sample at drying temperature range 45 ºC of air velocity at 2.4m/s.

C= Developed dryer blanched (75 ºC with 2min) dried mace sample at drying temperature range 45 ºC of air velocity at 2.4m/s.

It may be reveled from the table that the sun dried samples contain a volatile oil content of 9% (db), myristicin content of 1.582 and color difference of 23. Whereas unblanched mace sample dried in the developed dryer at heated air temperature range of 45 ºC and air velocity of 2.4m/s gave the values of 12.33% (db), 2.478 and 16.91 for volatile oil content, myristicin content and color difference respectively which clearly indicates that samples dried in developed dryer is superior

in quality. The values of the quality parameters obtained from samples which are blanched at 75 ºC for 2 min by dipping in hot water and then dried in developed drier at the optimum combination of drying air temperature and air velocity were higher than those of the values of unblanched samples. Therefore it may be recommended to have a pretreatment blanching for nutmeg mace prior to drying to obtain efficient drying and quality product John Zachariah *et al.*, (2004).

Plate A

Plate 3.8 : Sundried dried mace sample

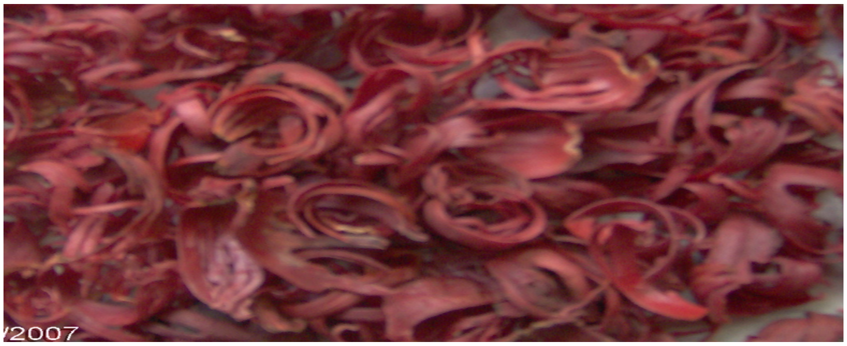

Plate B

Plate 3.9 :Unblanched dried mace sample

Plate C

Plate 3.10 : Blanched dried mace sample

Summary and Conclusion

SUMMARY AND CONCLUSION

Nutmeg (Myristica fragrance) is a tree spice, yielding two commercial spice products namely, Nutmeg and Mace, belongs to the family Myristicaceae. Nutmeg is the dried seed, while mace is the aril covering the outer surface of the seed. The yield of mace is about 15% that of nutmeg and it is the more expensive of the two spices both are stimulants, carminative, astringent and aphrodisiac and are used in pharmaceutical preparation for stomachache, flatulence, malaria and early stages of leprosy.

Conventionally, mace is dried in the sun or in kitchen fire place utilizing the heat from the stove. Some farmers dry mace on clay kurdis or sand medium spread over fire. These conventional methods result in loss of some volatile oil by evaporation and destruction of some of the heat sensitive pungent constituents. Also it is difficult to control the temperature of drying, which has a profound influence on the color of the dried mace. The dried mace so obtained does not posses uniform red color.

The sun drying is not an ideal practice because the harvesting season comes under active monsoon season. It requires 6-7 days for drying and also dried sample does not posses good color and is affected by mould growth. To offset these difficulties, a convective type nutmeg mace dryer was developed and its performance evaluated. The convective type dryer works on the principle of fluidization and therefore ensures efficient and uniform drying.

The developed dryer consist of a drying chamber, plenum chamber, heating coil box, air flow control and a blower with power source. The temperature of the heated air can be varied within certain ranges by switching ON/OFF either one or two of the heating coils and also by adjusting the air flow control valve. The velocity of air can be varied by varying the position of air flow control valve. Electric energy was used for heating the coil. The capacity of the developed dryer is 2kg/batch.

Based on a thorough review of literature and the preliminary studies conducted, three heated air temperature ranges viz. 40 ^{0}C, 45 ^{0}C and 50 ^{0}C and three velocities of the heated air viz. 1.6 m/s, 2.0m/s and 2.4m/s were taken as dependent variables for evaluation of the performance of the dryer. The parameter studied were the machine parameter such as drying rate, drying time and energy consumption and the product quality parameters such as volatile oil content, oleoresin content, myristicin content and color. All the quality analysis was carried out by standard methods.

The study was conducted as a two factor experiment on the basis of a completely randomized design (CRD). The results of the studies were then analyzed and an optimum combination of heated air temperature and air velocity was found. Based on these results a few samples were blanched by being dipped in hot water at 75^{0}C for 2 min and were dried in the developed dryer and its quality parameters found. A comparison was also carried out between the unblanched samples dried in the developed drier at the optimum conditions of heated air temperature and velocity and the samples dried under conventional sun drying method.

It was revealed from the study that unblanched samples dried at drying air temperature of 45 ^{0}C and with velocity of 2.4m/s produced better quality dried mace in terms of volatile oil content, oleoresin content, myristicin content and color.

Also the drying time was lower or equal to other treatments to lower the moisture content to 6% (wb). The energy consumption was only 1.9 kWh which was minimum with respect to the other combination therefore a drying air temperature of 45 ^{0}C and velocity of 2.4 m/s may be considered optimum for the developed drier.

It was also found that the total drying time in conventional sun drying method was 7-8 hrs were as the total drying was only 3.5 hrs in developed dryer. The volatile oil content, oleoresin content, myristicin content and color of the mace dried in the developed drier were significantly higher than those of the conventional sun drier samples. Mould growth was also observed in the sun dried samples. It was also established from the studies that blanching pretreatment prior to drying by dipping in hot water at 75^{0}C for 2 minute further increased the quality of the dried mace. The thermal efficiency of the developed dryer is 69% at the temperature of 45 ^{o}C.

The convective type nutmeg mace drier is simple in construction, efficient in operation and produces better quality mace. However the performance of the drier could be further enhanced by incorporating the suggestions listed below.

1. A part of the exhaust air may be recirculated to reuse the heat going out through exhaust.
2. Provisions for the use of alternative location specific fuel such as coconut shell etc may be provided.

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References

REFERENCES

Alzoreky, A.J. and Nakahara. 2002. Some Physical Properties of African Nutmeg. *International Agrophyscics*.21.PP:123-126..

Anonymous.1988.Status Paper on Spices, Spice Board,Calicut,India.PP.63-68.

AOAC. 1975. Official methods of analysis. Associates of Official Analytical Chemists, Benjamin Franklin Station, Washington, 563.

ASTA.1985. Official Analytical Methods. American Spice Trade Association, New York.

Balakrishnan, K.V.1992. An Insight into Spice Extractives. *Spice India*. 59:10, 2-6.

Clevenger, J.F.1952. Volatile Oil in Mace and Nutmeg. *Journal of Association Official Agricultural Chemists*.18,611-16.

Chakraverty, A. Post Harvest Technology of Cereals, Pulses and Oilseeds.2007. Oxford and IBH publishing co. pvt. Ltd. New Delhi.

Dann, A.E. Mathews, W.S.A. and Robinson, F.V.1977.Studies on the yields and compositions of Nutmeg and Mace oils from greneda. *Journal of Spices and Aromatic Crops*.21,456-62.

Dorman, D.G. and Deans, F. 2000. Chemical Composition of Nutmeg and Mace. *American Society of Agricultural Engineers*.39:5,1745-1750.

Gopalakrishnan, M. Thomas, P.P. Bhat, A.V. Varkey, A.G. Menon, N. and Mathew,A.G.1980. Post Harvest Technology of Nutmeg. In Processing Technology and Marketing:Proceedings of the Third Annual Symposium on Plantation Crops. *Indian Society for Plantation Crops*. Kasaragod. India.

Gopalakrishnan M. 1992. Chemical Composition of Nutmeg and Mace. *Journal of Spices and Aromatic Crops*.1,49-54.

Gopalan, C. Sastri, B.V. and Balasubramanian, S.C. 1981.Nutritive Value of Indian Foods. *Indian Council of Medical Research*, Hyderabad, India.

Hada, S. Hattori, Y. and Nanba, T. 1988. Phytochemistry, *Journal of Spices and Aromatic Crops* 27:2,563-568.

Hall, C.W. 1980. Drying and storage of agricultural crops. *American Society of Agricultural Engineers*. 42:2,421-425.

Hallstorm, H. and Thuvander, A.1997.Toxicological Evaluation of Myristicin. *Journal of Spices and Aromatic Crops* 5, 186-192..

Johnnkutty, P.C.1988. Chemical composition of nutmeg mace. *Indian Farming*.28:4,10-13.

John Zachariah, Krishnamurthy, 1992.In Vitro Proliferation of Nutmeg Aril by tissue Culture. *Journal of Spices and Aromatic Crops*.1:2,142-147.

John Zachariah, Rema, J and Krishnamurthy, 2004. Chemical Composition of Essential Oil of Nutmeg Mace. *Journal of Spices and Aromatic Crops*.13:2,135-139.

John Zachariah and Rema, J, 2004. Effect of Blanching and Drying on Quality of Mace. *Journal of Food Science and Technology*.41,306-308.

Khan, K.F. and Krishnaswamy, A.R.1953.A new Essential oil of Nutmeg and its Possible Uses.Sci.Jrnl.19:186-195.

Krishnamurthy and Mathew, P.A.2006.Nutmeg in Grenada. *Spice India*.PP:13-17.

Lewis, Y.S.1984.Spices and Herbs for the Food Industry. Food Trade Press Ltd. England.

Mallavarapu, G.R. and Ramesh, S.1998.Composition of Essential Oils of Nutmeg and Mace. *Journal of Medical and Aromatic Plant Science*.20,746-748.

Meyer, T.M.1941.Essentiol Oil from Leaves of Nutmeg. Eng.Netherlands-Indie.8:35-36.

Mohsenin N.N. 1970. Physical properties of plants and animal materials. *Gordon and Breach Science publication*. PP: 15-105.

Nair, M. K. 1994.Crop Dryers. Technical Bulletin No.29.Central Plantation Crops Research Institute (ICAR).Kasaragod. India.

Naves, Y.R.1974.Vegetative Propagation of Nutmeg in Grenada ,West Indias. *Tropical Agriculture*.41:141-46.

Nazeem, D.A. Nair, P.C.S. and Babu, L.C.1981.Flower Development, Floral Character and Pollination in Nutmeg. *Indian Cocoa,Arecanut,Spices,Journal*.5:2,29-32.

Paulose, T.P. and Thomas, P.P.2001.Drying of Fresh Green Cardamom in a Modified RRLT-NC Dryer Model 201.*Spice India*.PP:7-9.

Peter, S. and Rema, J. 2006. Essential Oil from Nutmeg. *Journal of Spices and Aromatic Crops*.13:6,135-139.

Prasad, S.1995. Estmation of Phenolic Acids in Nutmeg and Mace by High Performance Liquid Chromatography. *Journal of Spices and Aromatic Crops*.4:2,129-134.

Prasad, S Variyar. and Chiranjabi, Bandyopadhyay. 1995. Estimation of phenolic acids in cinnamon, Clove, Cardamom, Nutmeg and Mace by high performance liquid chromatography. *Journal of spices and aromatic plants.* 4:2,129-134.

Pruthi, J.S.1970. Quality evaluation of Spices III. Analytical pungent principles in black and white pepper. A critical appraisal. *Indian Spices*. 7:20, 21-23.

Pruthi, J.S.1979. *Spices and Condiments*, National Book Trust India, New Delhi,PP:166-172.

Pruthi, J.S. 1980. Spices and Condiments, chemistry, microbiology and technology. In Advances in Food Research, Academic Press, New York, 207.

Pruthi, J.S. and Krishnamurthy.1985. *Indian Cocoa Arecanut and Spices Journal*, 8:3.PP:75-77.

Pruthi J.S. 1992. Post-harvest technology of spices: Pre-treatments, Curing, Cleaning and Packaging. *Journal of food science and Technology.* 1,1-29.

Pruthi, J.S. 1993. Major spices of India: crop management, Post Harvest Technology, ICAR, New Delhi. PP: 44-46.

Purseglove, J.W. Brown, E.G. Green, C.L. and Robbins, S.R.J. 1981. *Spices*. Longman, New York. PP: 39-40.

Rema J and Krishnamurthy .1998.Effect of Packing Materials and Storage of Scions on Graft Success in Nutmeg. *Journal of Spices and Aromatic Crops*.7,147-148.

Rema,J.et.al.2006. Conservation of Wild Nutmegs of Andaman is at IISR. *Spice India*.PP:21-23.

Sadasivam S. Manickam A.1996. Biochemical Methods.2nd edn. *New Age International Pvt. Ltd*. New Delhi.

Salzer, U.1975.Analytical Evaluation of Seasoning Extracts and Essential oil from seasonings. *Journal of food science and Technology* 6:515-17.

Shanmugavelu, G.N. and Madhava Rao, V.1977. *Spices and Plantation Crops*. Popular Book Dept. Madras, India.

Shulgin, A.T. Sargrent, T. and Naronjo, C. 1970. The Chemistry and psychopharmacology of Nutmeg. Public Health Service Publication No.1645:202.

Sinclair, J. 1968. Flora Malesianae Precursores. The Genus Myristica in Malesia and outside Malesia. *Journal of Spices and Aromatic Crops*.1-150.

Tainter, W.A. and Grenis. 2001. Nutmeg Farming. *Journal of Spices and Aromatic Crops* PP:186-195.

Thomas, P.P. and Paulose, T.P. 2001. Drying of Fresh Green Cardamom in a Modified RRLT-NC Drier Model 201.*Spice India*. PP:7-9.

Thomson and Isaac.1967. Physcical and Chemical properties of Nutmeg and Mace *Journal of Spices and Aromatic Crops*.8,132-139.

http://commerace.nic.in/adjin_sun_tmbachina.htm

Appendices

APPENDIX A

EOA Specifications for Mace oil

Botanical Nomenclature: *Myristica fragrance* Preparation: By steam distillation of dried mace		
Physical and chemical characteristics	Appearance and odour	A colorless or pale-yellow liquid having the characteristic odour and taste of nutmeg
	Specific gravity at 25^{o} C	0.880 to 0.930
	Optical rotation	+2^{0} to + 30^{0}
	Refractive index at 20^{o} C	1.4740 to 1.4880
	Solubility in 90% alcohol	Solubility is 3.0 volume

(Ref: Purseglove *et al*., 1981)

APPENDIX B

EOA Specifications for Mace oleoresin

Botanical Nomenclature: *Myristica fragrance* Preparation: By steam distillation of dried mace		
Physical and chemical characteristics	Appearance and odour	A clear red, amber or dark red liquid with characteristic odour and flavor of oil of nutmegs
	Specific gravity at 25^{o} C	0.955 to 1.005
	Optical rotation	-2^{0} to + 45^{0}
	Refractive index at 20^{o} C	1.4690 to 1.5000
	Residual solvent in oleoresin	Meets with federal food, Drug and Cosmetic act regulation

(Ref: Purseglove *et al*., 1981)

APPENDIX C

Details of the precision balance used for measurement of weights

1. Manfacture	-CONTECH instrument company 32 & 33/2, Bhandup Industrial Estate Pannalal Compound, L.B.S marg, Bhandup (west), Mumbi-400 078
2. Type	- CONTECH- precision balance-CB series
3. Description	- Electronic balance high accuracy class 2^{nd}
4. Model	-CB 300, Class 2^{nd}
5.Sr. No	-952434
6. Capacity	- 300(g) maximum
7 Power	- 230V Ac, 50Hz
8.Temperature range	-15 ^{o} C -40 ^{o} C

APPENDIX D

Capacity of Dryer

The capacity of drier was taken after considering the average yield of mace per season for an average farmer. The capacity of the drier is taken as 2 kg. It was calculated as follows

Total yield of mace per season for an average farmer = 60 kg

Mace to be dried per season = 60 kg

Taking 30 drying per season the quantity of mace to be dried

Per drying = $\frac{60}{30}$ kg

The design capacity of the dryer = 2 kg/batch

We are providing 0.2m diameter cylinder

$\therefore$ The area of drying chamber = 0.0314 m^2

Abstract

DEVELOPMENT AND EVALUATION OF A CONVECTIVE TYPE DRYER FOR NUTMEG MACE

(*Myristica fragrans houtt.)*

CHIKKANNA, G.S.

ABSTRACT OF THE THESIS REPORT

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In

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Faculty of Agricultural Engineering and Technology

Kerala Agricultural University, Vellanikkara, Thrissur

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ABSTRACT

A convective type nutmeg mace dryer was developed and its performance was evaluated. The major parts of the developed dryer are Drying chamber, Plenum chamber, Heating coil box, Air flow control and Blower with power source. The dryer was evaluated at three different air temperatures of 40 ºC, 45 ºC and 50 ºC and at three air velocities 1.6 m/s, 2.0 m/s and 2.4 m/s. Unblanched samples dried at drying air temperature of 45 ºC and with air velocity of 2.4 m/s produced better quality dried mace in terms of volatile oil content, myristicin content, oleoresin content and color. Also at this treatment combination the drying time was lower and the energy consumption minimum. It was also found that the quality of the dried samples in the developed dryer is superior to conventional sun drying method. It was also established from the studies that blanching pretreatment prior to drying by dipping in hot water at 75 ºC for 2 min further increased the quality of dried mace. The convective type nutmeg mace drier is simple in construction, efficient in operation and produces better quality mace.