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Comparison of drying characteristics and quality of nutmeg mace (*Myristica fragrans*) by different drying methods

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Abstract

The experiments on drying of nutmeg mace inside solar tunnel dryer with biomass back up and in a mechanical dryer at three varying temperatures of 45, 50 and 55 °C was evaluated. The process of drying nutmeg mace in solar tunnel dryer was completed in 33 h while in mechanical dryer, at drying temperatures of 45, 50 and 55 °C, nutmeg drying was completed in 105, 102 and 78 h. Physical properties like moisture (5.48%), bulk density (171.49 kg/m^3) and dry recovery (33.56%) were obtained for nutmeg mace dried in solar tunnel dryer with biomass backup. Maximum retention of essential oil (9.07%) and oleoresin (33.49%) was obtained in nutmeg mace dried in a mechanical dryer at 45 °C while lycopene content (186.57%) was highest in nutmeg mace dried in mechanical dryer at 55 °C. Mechanical drying at a temperature of 55 °C could complete the drying process of mace in 6 h The important constituents identified in nutmeg mace oil were sabinene, saffrole, elemicin, limonene, myristicin, α-pinene, β-pinene, β-myrcene, careen, α-terpinene, γ-terpinene, terpinolene, terpineol, eugenol methyl ether and α-Thujene.

Keywords: Drying characteristics, *Myristica fragrans*, nutmeg mace, quality

Introduction

Nutmeg (*Myristica fragrans* Houtt.) produces two different spices from the same fruit *ie*. nutmeg and mace and is distributed in India along the western ghats and across south east Asian countries and in the Pacific Islands. (Krishnamoorthy and Rema, 2000) [8]. Fruiting commences from fifth or sixth year and sometimes it may even take eight or nine years (Vergheese *et al*. 1990) [17]. Fruits are reported to ripe in 6-9 months after flowering (Nazeem, 1979) [13]. In India, harvesting is carried out when the fruits split open on the tree exposing the brilliant red coloured aril (Nair *et al*. 1997) [13]. In Konkan region, the peak harvesting period is confined from June to October, whereas in Kerala harvesting is done during June-July (Nybe *et al*. 2006) [15]. A good tree in full bearing on an average yields about 3000 fruits between 15 to 30 years of growth. A single nutmeg fruit weighs about 60 g out of which the fresh seed weighs 6-7g while the mace weighs 3-4 g and the remaining is pericarp. Ratio of nutmeg to mace is 8:1. Fruits are collected manually by hand plucking from the tree or by using a hooked stick but generally the fruits are allowed to fall down on the ground naturally and handpicked every day (Krishnamoorthy, 1987) [7].

After harvest, the fleshy outer rind called as pericarp is separated and the aril that covers the shell called as mace, is peeled off manually. In good dry weather, the drying operation is accomplished in two or three days. Sun drying leads to a certain amount of colour fading. To prevent such bleaching artificial drying is often resorted to. A perfect sample of mace is bright red in colour consisting of entire double blades, not broken, flattened and of large size, horny in texture and not too brittle (Nybe *et al*. 2006) [15]. In Kerala, the harvesting season coincides with the monsoon season. So sun drying often becomes impossible. Hence, it was necessary to develop alternate drying system to dry nutmeg mace during monsoon season. Thus, the present work was undertaken for evaluating a solar tunnel dryer provided with biomass backup in comparison to a mechanical dryer and to study the drying characteristics and physicochemical quality attributes of dried mace.

Materials and Methods

The fresh nutmeg mace sample (variety Viswasree) of ICAR-IISR, Peruvannamuzhi, Kozhikode, Kerala was used for the experimental studies.

A digital EQUINOX make (EQ-32S model) hand held temperature/RH meter and a digital lux meter (TES1332A) was used to determine the temperature, relative humidity and solar intensity both inside and outside the solar tunnel dryer. Since the experiments were conducted during rainy season, the solar intensity inside the tunnel dryer with was below 400 Wm^{-1} and hence alternate heating arrangements to increase the temperature inside the tunnel dryer was done by burning coconut husk and wooden logs in the furnace of backup.

The experiment on drying of nutmeg mace was conducted by two methods *ie.* in a solar tunnel dryer with biomass backup (Fig. 1) and in a mechanical dryer at varying temperatures of 45, 50 and 55 °C, during the month of July 2014 at the Experimental Farm of ICAR-IISR, Peruvannamuzhi, Kozhikode, Kerala.

Two kg of fresh nutmeg mace were spread in stainless steel trays of size 90 cm x 90 cm. The trays were mounted on mild steel stand and three such trays were placed in the solar tunnel dryer with biomass backup (Fig. 2). The observations were taken every 3 h and the loss in mass was recorded till a constant mass was obtained. Three such replicates were maintained.

Fig 1: Solar tunnel dryer with biomass backup

Fig 2: Drying of nutmeg mace in solar tunnel dryer with biomass backup

The solar tunnel dryer with biomass backup was installed at Experimental farm at Peruvannamuzhi and has a drying chamber of size 9 m × 4 m of height 2.6 m. The drying chamber is semi cylindrical hoop shaped structure which is covered with a transparent 200 microns, polyethylene UV-stabilized sheet. The unit has an opening for air entry of size 0.609 m x 0.609 m and provided with a mild steel door of size 2 m x 1m. A ‘C-shaped’ air duct is provided on the floor that runs throughout the length of the dryer which is about 6.7 m long, 0.3 m in wide and depth of 0.3m. The ducts have vents on the top to distribute the air equally into the drying chamber. Totally there are 8 vents each having dimension of 0.5 x 0.03 m. Two numbers of exhaust fans are fixed in the air outlet for flushing out the air from the drying chamber. A mild steel biomass furnace of size 112 cm × 71 cm × 71 cm is placed near the solar tunnel dryer and serves as backup by generating heat. It is provided with three doors through which biomass were provided.

Drying Characteristics

Mechanical drying of mace was done in hot air oven (Memmert, Germany, temperature range of 20 °C to 300 °C). The experiments on drying of nutmeg mace were performed at different temperatures of 45, 50, and 55 °C to study the effect of temperature on physicochemical qualities of dried nutmeg mace. Nutmeg mace (two kg) was spread over the perforated trays of dryer (Fig. 3) and during drying the observations of loss in mass was recorded at an interval of 3 h until the drying mass was constant.

The drying characteristic curves represented by the plot of moisture content, moisture ratio and drying rate versus drying time were drawn (Chakraverty, 1988) [3]. Various parameters represented in the drying characteristics were calculated as follows:

The moisture content in dry basis (db) was determined as the ratio of the mass of moisture in the sample (kg) to the mass of bone dry material (kg).

The moisture ratio (MR) (Midilli, 2001) [11] for long drying period was calculated as the ratio between the moisture content at time t (M_t in % db) to the initial moisture content (M_0 in % db)

$$MR = \frac{M_t}{M_o}$$

The drying rate ‘R’ is calculated as the ratio of amount of water removed (Q_r in kg) per unit time (t in h) per unit mass of dry matter (W_{bd} in kg) and is represented as follows (Erenturk *et al*. 2004) [4]:

$$R = \frac{Q_r}{t \times W_{bd}}$$

Quality analysis

The dried samples of nutmeg mace obtained by solar and mechanical drying methods were evaluated for both physical and biochemical qualities. The physical properties determined were moisture content by toluene method (ASTA, 1968) [2], bulk density calculated as the ratio between mass of the mace in a given volume to the volume of the container (Mohsenin, 1986) [12] and the percentage dry recovery was determined as the ratio of dried mace obtained to the initial mass of fresh mace (Mohsenin, 1986) [12].

The biochemical methods described by Sadasivam and Manickam, (2008) [16] was followed to estimate total carbohydrate (Anthrone method), fat content (Soxhelet extraction method) and lycopene content (petroleum ether extraction and the absorbance was read at 503 nm). The soluble protein content was determined by the procedure described by Lowry *et al.* (1951) [10]. The method described by ASTA (1968) [2] was used to determine the essential oil content (modified Clevenger method) and oleoresin content (extraction using petroleum ether).

A gas chromatograph with mass spectroscope (Shimadzu GC 2010 and Shimadzu spectroscope QP -2010) and capillary column (RTX-WAX, 30M× 0.25MM id × 0.25 um) was used to analyse the constituent of the essential oil by injecting 0.1

µl through the injection port (The injection port temperature was 250°C, flow rate of 1 ml/min, linear velocity of helium carrier gas was 48.1 cm/s, split ratio was 50 and having 70 eV of ionization energy). The data obtained on physicochemical quality of dried nutmeg was statistically analyzed by single factor completely randomized block design using statistical software AGRES (Ver. 7.01).

Results and Discussion

Drying characteristics of nutmeg mace

The maximum ambient temperature of 30.53 °C was obtained at 13.00 h and minimum of 26.46 °C was recorded at 9.00 h. While the maximum relative humidity of 89.31% was observed at 9.00 h and minimum of 83.41% was obtained at 13.00 h (Fig. 3). Sun shine intensity outside the solar tunnel dryer could not be measured due heavy rain. The solar tunnel dryer was supplemented with external heat by burning biomass like wooden logs and coconut husks (69.93 kg/ day of 8 h).

The maximum temperature of 48.95 °C corresponding to minimum relative humidity of 41.68% was observed at 13.00 h inside the solar tunnel dryer. While the minimum temperature of 27.93 °C corresponding to maximum relative humidity of 86.55% was recorded at 9.00 h was obtained at 13.00 h and the minimum relative humidity of 41.68% was recorded at 9.00 h (Fig. 4). The average sun shine intensity inside the solar tunnel dryer was maximum at 13.00 h (244.67 Wm^{-2}) and minimum of 16 Wm^{-2} was recorded at 9.00 h.

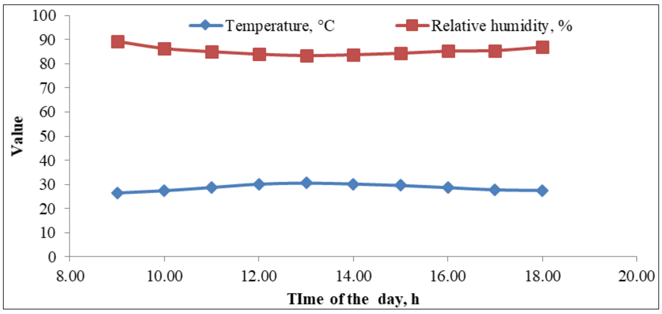


Fig 3: Variation in temperature and relative humidity under ambient conditions

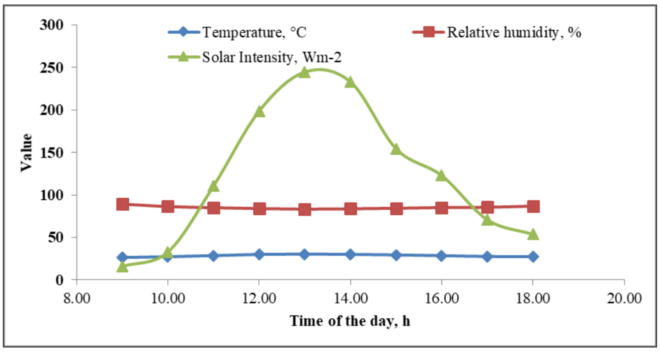


Fig 4: Variation in temperature, relative humidity and solar sunshine intensity inside a solar tunnel dryer with biomass backup

Drying characteristics curves indicated that as the drying time increased, the moisture content of nutmeg mace was found to decrease (Fig. 5a). Nutmeg mace had initial moisture content of was 225.32% (d.b) and after drying for 2 days (33 h) in a solar tunnel dryer during rainy season with biomass backup, the moisture content reduced to 5.64% (d.b). In case of mechanical dryer, drying at a temperature of 45 °C, the moisture content of nutmeg mace reduced from 225.32 to 4.98% (db) in about 9 h to reduce. While for drying at a temperature of 50 and 55 °C, took 8 h and 6 h to reduce to a final moisture content of 4.70% (db) and 4.36% (db), respectively.

Amaladhas *et al.* (2004) [1] reported that blanching nutmeg mace at 75 °C for 2 min followed by drying in an agricultural waste-fired dryer at 50 °C, the drying was completed within 4 h and yielded good quality mace.

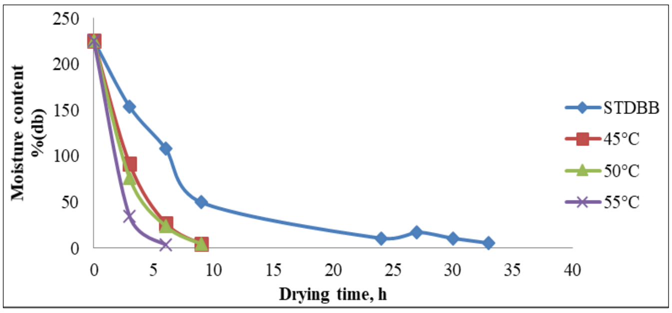


Fig 5a: Moisture content of nutmeg mace verses drying time

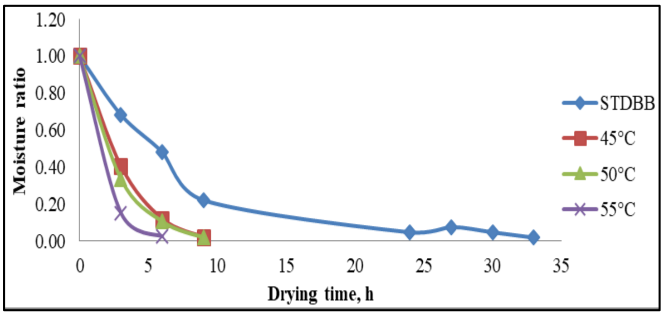
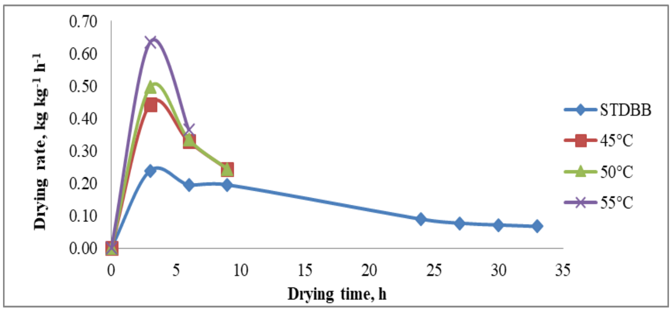


Fig 5b: Moisture ratio of nutmeg mace verses drying time



STDBB- solar tunnel dryer with biomass backup

Fig 5c: Drying rate of nutmeg mace verses drying time

Quality analysis

Nutmeg mace dried in solar tunnel dryer with biomass backup showed maximum retention of moisture (5.48%), bulk density (171.59%) and dry recovery (33.56%). While for mechanical drying, as the drying temperature increased, it was observed that the moisture content, bulk density and dry recovery there was found to decrease. Significant influence in moisture content and bulk density ($p \leq 0.05$) was observed but no significant effect on the dry recovery of the mace was observed due to variation in drying methods (Table 1).

Table 1: Physical properties of nutmeg mace

Drying methods	Moisture (%)	Bulk density (kg/m³)	Drying time (h)	Dry recovery (%)
Solar tunnel drying with biomass backup	5.48	171.59	33	33.56
Mechanical drying at 45°C	4.98	162.70	9	32.85
Mechanical drying at 50 °C	4.70	144.00	8	32.60
Mechanical drying at 55 °C	4.36	136.50	6	32.20
SED	0.19	8.51	0.40	1.57
CD at 5%	0.48*	20.82*	0.99**	3.88(NS)

Note: * - significant at 5%, **- significant at 1%, NS- non significant

Amaladhas *et al.* (2004) [1] reported the dry recovery of blanched and unblanched nutmeg mace was 37.14 and 37.8%, respectively. Kumar *et al*. (2017) [6] reported that maximum dry recovery of 48.50% was obtained for sun dried nutmeg mace at residual moisture content of 9.63%.

Biochemical analysis showed that maximum retention of carbohydrate (44.18%), protein (1.56%) and essential oil content of (9.07%) was obtained for nutmeg mace dried in mechanical dryer at 45 °C. Fat content was highest (14.17%) for mace dried in solar tunnel dryer with biomass backup. However, retention of constituents like the essential oil (9.07%) and oleoresin (33.49%) was highest when dried in a mechanical dryer at 45 °C while lycopene content (186.57%) was highest for mace dried in mechanical dryer at 55 °C (Table 2). Analysis of variance showed no significant variation in constituents like protein and lycopene content but there was significant variation ($p \leq 0.01$) in other constituents due to drying methods by different drying methods.

Table 2: Biochemical properties of nutmeg mace dried by different drying methods

Drying methods	Biochemical properties					
	Carbohydrates (%)	Fat (%)	Protein (%)	Essential oil (%)	Oleoresin (%)	Lycopene (%)
Solar tunnel drying with biomass backup	42.51	14.17	1.50	7.82	29.41	180.71
Mechanical drying at 45 °C	44.18	13.66	1.56	9.07	33.49	181.37
Mechanical drying at 50 °C	42.08	12.47	1.51	8.40	32.35	184.81
Mechanical drying at 55 °C	39.84	12.01	1.51	8.27	30.69	186.57
SED	0.53	0.21	0.051	0.12	0.81	3.31
CD at 5%	1.31**	0.52**	0.03(NS)	0.29**	0.98**	7.67(NS)

Note: * - significant at 5%, **- significant at 1%, NS- non significant

Gopalakrishnan (1992) [5] reported that starch was the predominant constitutent in nutmeg mace (44%), Proteins (9.91%), crude fibre (3.93%) and ash 1.56% on dry weight basis. Further, the essential oil content of nutmeg mace was 15.30% on dry weight basis. Amaladhas *et al.* (2004) [1] conducted quality analysis of both blanched and un blanched nutmeg mace and reported that the volatile oil and oleoresin yields in un blanched nutmeg mace were 12.16 and 23.88% (db) while the lycopene content was 156.99 mg/100g.

The profiling of essential oil of nutmeg mace dried by different drying method was determined using gas chromatography mass spectroscopy (Table 3). The important constituents identified in nutmeg mace oil were sabinene (15.86 to19.66), saffrole (12.63 to 15.20), elemicin (6.04 – 7.15), limonene (5.23 to 6.96), myristicin (3.42 to 5.28), α-pinene (5.65 to 6.95), β-pinene (5.09 to 6.47), β-myrcene (2.11 to 3.22), careen (2.38 to 3.17), α-terpinene (3.37 to 4.47), γ-terpinene (5.09 to 6.67), terpinolene (2.62 to 3.42), terpineol (1.33 to 3.38), eugenol methyl ether (1.23 to 3.39) and α-Thujene (1.90 to 2.74). Nutmeg mace dried in solar tuunel dryer with biomass backup recorded the maximum retention of sabinene (15.86%), β-pinene (6.47%), limonene (6.96%), terpineol (3.42%), eugenol methyl ether (3.39%) and myristicin (5.28%). There was a significant increase ($p \leq 0.05$) in constituents like α- α-pinene, Thujene, β-pinene, careen, α-terpinene, β-myrcene, limonene, γ-terpinene, terpinolene and with increase in drying temperature in a mechanical dryer as indicated by analysis of variance showed.

Gopalakrishnan (1992) [5] reported that mace oil yielded higher concentrations of myristicin (5.92%) and elemicin (3.14%) while Leela (2008) [8] reported the mace oil from Karnataka, contained sabinene (23.5%), terpinen-4-ol (23.6%), elemicin (10.5%) and γ-terpinene (6.6%) as important constituents.

From the study, it was concluded that a multipurpose solar tunnel dryer with biomass backup could be utilized for drying nutmeg mace during rainy season and when mechanical drying was opted a temperature of 55 °C could be adopted to complete the drying process in 6 h.

Table 3: Volatile oil constituents of nutmeg mace dried by different drying methods

Drying methods	α-Thujene, %	α-pinene, %	Sabinene, %	β-pinene, %	β-myrcene, %	careen, %	α-terpinene, %	Limonene, %	γ-terpinene, %	Terpinolene, %	Safrole, %	terpineol, %	Eugenol methyl ether, %	Myristicin, %	Elemicin, %
STDBB	1.90	6.30	19.66	6.47	3.14	3.04	3.37	6.96	5.09	3.34	12.63	3.38	3.39	5.28	6.04
MD45 °C	1.74	5.65	17.51	5.09	2.11	2.38	3.56	5.23	6.31	3.42	13.96	2.32	2.32	5.20	5.96
MD50 °C	2.23	6.47	16.79	5.81	2.72	3.10	3.95	6.07	6.32	3.18	14.20	1.59	1.46	4.55	6.45
MD55 °C	2.74	6.95	15.86	6.22	3.22	3.17	4.47	6.53	6.67	3.37	15.20	1.33	1.23	3.42	7.15
SED	0.20	0.20	0.76	0.25	0.096	0.32	0.29	0.22	0.42	0.32	0.29	0.58	0.58	0.79	0.50
CD (5%)	0.50*	0.49*	1.87*	0.62*	0.23*	0.80(NS)	0.73*	0.55*	1.02*	0.78(NS)	0.72*	1.44*	1.44*	1.93(NS)	1.23*

Note: * - significant at 5%, **- significant at 1%, NS- non significant, STDBB- solar tunnel drying with biomass backup; MD-mechanical drying

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