Journal of Spices and Aromatic Crops
Vol. 31 (1) : 65-74 (2022)
10.25081/josac.2022.v31.i1.7698

Indian Society for Spices

Effect of curing methods on quality and drying characteristics of turmeric

Tshering Ongchu Lepcha, Shrilekha Das*, Babli Dutta & P S Medda

Department of Plantation Crops and Processing, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar (W.B), India.
**Email: shri137@gmail.com*

Received 12 May 2022; Revised 08 June 2022; Accepted 18 June 2022

Abstract

Turmeric rhizomes of Suranjana cultivar were cured by traditional and microwave methods in water and sodium bicarbonate solution and dried in hot air dryer. Effect of curing methods on moisture content, hardness, colour, curcumin content, essential oil content, total phenolic content and drying rate were investigated. Curing methods did not have significant effect on moisture content of cured rhizomes. Hardness of turmeric rhizomes decreased as curing duration increased. Microwave curing in sodium bicarbonate solution for 6 min resulted in maximum value of the colour indices, highest curcumin content (5.20%) and essential oil content (4.38%) in turmeric powder and highest dry recovery (24.20%). Curing caused significant reduction in drying time. Minimum drying time (20.84 h) was required in microwave curing in water for 8 min, whereas, uncured samples took longest time (29 h) for drying. Drying of all the turmeric rhizomes cured by different methods occurred in falling rate period.

Keywords: colour, *Curcuma longa*, curcumin, drying rate, essential oil, phenolic content

Introduction

Turmeric (*Curcuma longa* L.) is one of the most important rhizomatous crops. India had 2,96,181 hectares under turmeric cultivation with a total production of 11,78,750 tonnes during 2019-20 (Spice Board, 2021). Turmeric requires assured water supply almost throughout the year for 8 to 9 months (Thiyagarajan *et al*. 2011). Curcuminoids, a group of fat-soluble polyphenolic pigments, are responsible for the bright yellow colour and medicinal and therapeutic properties of turmeric (Asghari *et al.* 2009). The curcuminiods include curcumin, demethoxycurcumin, bis-demethoxycurcumin and cyclocurcumin of which curcumin is the major bio-active constituent (Wakte *et al.* 2011). The phenolic content in turmeric rhizomes, including curcuminoids, contributes to the antioxidant effect of the spice (Tilak *et al*. 2004). Turmeric is used as an antioxidant, digestive, anti-microbial, anti-inflammatory and anti-carcinogenic agent (Meng *et al.* 2018). It helps in controlling the cholesterol level. It is also efficient in the treatment of liver diseases, dermatological disorders and in blood purification (Khanna 1999).

Fresh turmeric rhizomes are cured for obtaining dry turmeric for marketing. Traditional curing process involves boiling of fresh rhizomes in water for 45 – 60 min in copper or galvanized iron or earthen vessels. Boiling destroys vitality of fresh rhizomes, removes raw odour, reduces drying time and yields uniformly coloured product (Jayashree & Zachariah 2016). Curing results in modification (gelatinization) of the starch to obtain uniform drying, softer texture and produce turmeric with better curcuminoid content and uniform pigment distribution (Prathapan *et al*. 2009). Boiling in alkaline water improves the colour of dried powder with orange yellow colour (Weiss 2002; Reddy 2017). Overcooking of rhizome leads to colour deterioration and undercooking makes it brittle. When the rhizome yields to finger pressure and can be perforated by a blunt piece of wood it is considered as optimum curing.

Curcumin content in turmeric powders has been reported to depend on the variety, method of processing and drying temperature (Jayaprakasha *et al*. 2002; Venkateshwari *et al*. 2021). Use of some specific type of boiling system or heat exchanger, pressure applied during boiling and duration also influence the quality of turmeric (Farzana *et al*. 2018; Mayure *et al*. 2018; Kebede *et al*. 2021). Using steam for curing reduces drying time and yields good quality product (Sangha & Mittal 2021). Significant loss of curcumin (27–53%) from heat processing has been reported (Suresh *et al*. 2007). Microwave curing of cut pieces of turmeric has recently been studied to eliminate certain disadvantages of conventional curing methods, such as, leaching of curcumin and oleoresins, energy and labour intensive and over-cooking of rhizomes due to prolonged heating (Hmar *et al*. 2017). Dielectric heating causes vaporization of volatile compounds which in turn leads to swelling and rupturing of the cells (Dandekar & Gaikar 2002). This phenomenon leads to textural modification. Microwave heating has been used as an efficient blanching process to inactivate enzymes in fruits and vegetables as the nutrient loss through leaching is less when compared to conventional hot water blanching (Vadivambal & Jayas 2007). The curing time significantly affects the drying time (Hmar *et al*. 2017; Bhat & Hedge 2018). Curing for longer duration softens the tissues and enhances the removal of water at a faster rate. In the present study, effects of different methods of curing, including conventional, improved and microwave methods were investigated on the quality and drying rate of Suranjana variety of turmeric.

Materials and methods

Freshly harvested turmeric rhizomes of Suranjana variety were collected from the instructional plots of Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal in the month of February 2019. The rhizomes were washed thoroughly to remove soil, other foreign matter and roots. The mother rhizomes were separated from the finger rhizomes manually and finger rhizomes were cured by seven different treatments and each treatment was replicated three times. For each treatment 1 kg washed rhizome was used.

Curing methods of turmeric rhizomes

Washed fingers of turmeric rhizomes were cured by conventional and microwave method. Whole fingers from the rhizomes were used in every method with water or sodium bicarbonate ($NaHCO_3$) solution at a rate of 2.5 L kg^{-1} of sample in different treatments. In the only earlier study involving microwave curing of turmeric rhizomes by Hmar *et al*. (2017), the optimum duration was reported as 4 min at 900 W output power for 1 cm cubes. Since there are chances of leaching and loss of solutes from cut pieces, whole finger rhizomes were cured in this study. Considering the larger dimensions of the rhizomes and after conducting some preliminary trials on microwave curing/boiling, the duration of microwave curing was fixed at 6 min and 8 min.

Conventional curing (CC) and improved conventional curing (ICC)

Washed turmeric rhizomes were taken in stainless steel container and were cured in boiling water for conventional curing (CC) and in alkaline solution of 0.1% sodium bicarbonate ($NaHCO_3$) for ICC for 45 min.

Microwave curing (MC6 and MC8)

Washed turmeric rhizomes were taken in Borosil glass container with water in a microwave oven (LG Healthwave cooking system, MG 607 APR). Microwave treatment was applied with an output power of 900W for 6 min (MC6) and 8 min (MC8).

Microwave improved curing (MIC6 and MIC8)

$NaHCO_3$ solution was used with washed turmeric rhizomes in Borosil glass container for microwave treatment at an output power of 900W for 6 min (MIC6) and 8 min (MIC8). Samples from the uncured and cured turmeric rhizomes were taken for analysis of hardness.

Drying and grinding of turmeric

After draining off the water or alkaline solution, cured turmeric rhizomes were dried in tray dryer at air temperature of 60 ^{o}C until it reached 10 – 12% moisture content (w.b.). Weight of the turmeric rhizomes in each treatment was recorded at 1 h interval for initial 5 h and at 2 h interval for the rest of the drying period for analysis of rate of drying. Weight measurements of the samples were taken using digital weighing balance (Mettler Toledo Model no: PB153-L). Dry recovery of turmeric from different treatments was calculated from the weight of fresh and dried rhizomes weight and expressed in percentage. Dried turmeric rhizomes were ground into powder with the help of a mixer grinder machine (Bajaj Mixer Grinder GX8).

Dimension and number of fingers in 250 g sample

The length and dimension of 20 fresh fingers of turmeric rhizomes were measured using digital caliper (CD-8 CSX). The largest and smallest diameter of each finger was measured. The average diameter and length of turmeric fingers were used for calculation of drying area. Three samples of 250 g each were taken from fresh turmeric fingers and the number of fingers in each 250 g sample was counted. The average number of fresh turmeric fingers was calculated.

Drying rate

Drying rate (*R*) is defined as the amount of moisture removed per unit area per unit time. Total surface area of the fingers dried was calculated from the average length, diameter and number of fingers dried per treatment. Change in moisture content of turmeric rhizomes during drying was calculated from the weight loss and initial moisture content. Drying rate (*R*) was calculated as,

$$R = \frac{\text{kg/moisture removed}}{\text{m}^2.\ \text{min}}$$

Analysis of moisture content

For analysis of moisture content, oven drying method was used (Maniglia *et al*., 2015). Turmeric rhizomes from different treatments were thinly sliced and dried in hot air oven at 100 ^{o}C for 24 h, until it reached constant weight. Moisture content (wet basis) was calculated from the weight of rhizomes before and after drying, recorded using weighing balance (METTLER TOLEDO, Model no: PB153-L).

$$\text{Moisture content (wet basis \%)} = \frac{\text{weight of fresh turmeric} - \text{weight of dry turmeric}}{\text{weight of fresh turmeric}} \times 100$$

Analysis of hardness of cured and uncured rhizomes

Compression test for estimation of textural degradation in terms of hardness of fresh and cured turmeric rhizome was performed using Texture Analyzer (Stable Micro Systems, Model: TA.HD plus) on a slice of turmeric rhizome with 1 cm thickness. An Ottawa plunger with a load cell of 50 kg was used to check the hardness of the cured samples for 20% strain.

Analysis of colour of dried turmeric powder

Colour of all treated turmeric samples after drying and grinding was analysed by using HunterLab colorimeter (Colour Quest XE). The powder was taken in HunterLab colour measure glass optical cell (50 mm) light path. *L* (lightness index), *a* (redness index), *b* (yellowness index) values of all the samples were recorded.

Analysis of curcumin content in dried turmeric powder

Curcumin content of each sample was measured by spectrophotometric method (Madhusankha *et al*. 2018). Fresh and cured turmeric powders were extracted with methanol and diluted to a concentration of 200 ppm. Absorbance of this extract at 425 nm was recorded by UV/Vis Spectrophotometer (Shimadzu, Model No. UV1800ENG240V, SOFT). Curcumin content was estimated from the standard curve prepared by using standard curcumin (Himedia) of different concentrations.

Analysis of essential oil content in dried turmeric powder

Essential oil content in the turmeric powder from each treatment was analyzed by using soxhlet apparatus (Pelican Equipments, model: Socsplus-SCS 04R) with petroleum ether as solvent (Roohinejad *et al*. 2017) at 90 °C for 50 min (for extraction) and 180 °C for 15 min (for evaporation of solvent).

Analysis of total phenolic content in dried turmeric powder

For estimation of phenols in dried turmeric samples, spectrophotometric method using Folin-ciocalteau reagent was followed (Prathapan *et al*. 2009). Fresh and cured turmeric powders were extracted with 80% ethanol and centrifuged at 10000 rpm in Sigma 2-16KL centrifuge for 10 min. The supernatant was evaporated to dryness using hot water bath. The residue was dissolved in distilled water and Folin-Ciocalteau reagent was added thoroughly. The absorbance at 650 nm was recorded by UV/Vis spectrophotometer (Shimadzu Model No. UV1800ENG240V, SOFT). Total phenolic content was estimated from the standard curve prepared using standard gallic acid of different concentrations.

Statistical analysis

The observations recorded in laboratory from different treatments were subjected to statistical analysis using OPSTAT software. Treatment variations were tested for significance using critical difference test at 5% level of significance ($p \leq 0.05$) by consulting Fisher and Yates table.

Results and discussion

Moisture content, hardness and colour of turmeric rhizomes

Moisture content of fresh and cured turmeric from different methods ranged between 80.06 – 82.45% (wet basis) and this variation in moisture content was not significant. Table 1 shows the change in hardness of fresh and cured rhizomes as analyzed by compressive testing. Hardness of the turmeric rhizomes varied significantly among different treatments. Hardness of uncured rhizomes was quite higher than that of cured rhizomes (Table 1). Decrease in hardness of cured turmeric rhizomes compared to uncured rhizomes can be attributed to softening of tissues due to loss of turgor as membrane disrupts during thermal processing (Buggenhout *et al*. 2009). Minimum hardness of rhizome (3388.33 g) was

Table 1. Effect of curing methods on hardness of cured and fresh turmeric rhizomes

Curing method	Hardness (g)
UC	16053.17
CC	4658.67
ICC	4548.64
MC6	5168.20
MIC6	4814.30
MC8	4312.57
MIC8	3388.33
SEm (±)	1005.33
CD at 0.05	3078.89

observed in MIC8 (microwave treatment with 0.1% $NaHCO_3$ solution for 8 min). Microwave cured samples showed higher tissue softening than conventional cured samples. Higher textural degradation in microwave treated turmeric rhizomes was also observed by Hmar *et al*. (2017) in cut samples. Pectin solublization occurs during processing at high temperature by non-enzymatic mechanisms leading to decrease in cell-cell adhesion (Diaz *et al*. 2007; Sila *et al*. 2008). This might also have contributed to texture degradation in cured samples.

Colour of dried turmeric powder samples was analyzed by HunterLab colorimeter (Color Quest XE) and colour components *L*, *a*, *b* of the samples had significant variation among different curing methods. Fig. 1 shows the variation in colour components of turmeric powder samples. The powder obtained from uncured rhizomes had lowest value of yellowness index *b* and the powder obtained from MIC6 (microwave treatment with 0.1% $NaHCO_3$ solution for 6 min) had maximum value of brightness *L*, (58.94), redness index *a*, (26.74) and yellowness index *b* (57.68). Longer duration of microwave treatment (MIC8) caused a decrease in colour parameters. Improved colour values in heat treated turmeric powder were also reported by Prathapan *et al*. (2009). Heat/microwave treatment of rhizomes prior to drying can inactivate oxidative enzymes (Govindarajan 1980), which are responsible for dark brown colour of rhizomes.

Curcumin content of turmeric rhizomes

Curcumin content varied between 4.19% (CC) and 5.20% (MIC6) in different curing methods, as presented in Table 2. It was observed that microwave treatment for 6 min (MC6 and MIC6) improved curcumin content in rhizomes as compared to conventional curing methods (CC and ICC). But increasing the duration of microwave treatment (MC8 and MIC8) resulted in lower curcumin content. More severe thermal process may have affected the stability of bioactive compounds like curcuminoids. Decrease in curcumin content by severe heat treatment has also been reported by Suresh *et al*. (2007) and Jayashree & Zachariah (2016). Microwave treatment for curing of turmeric

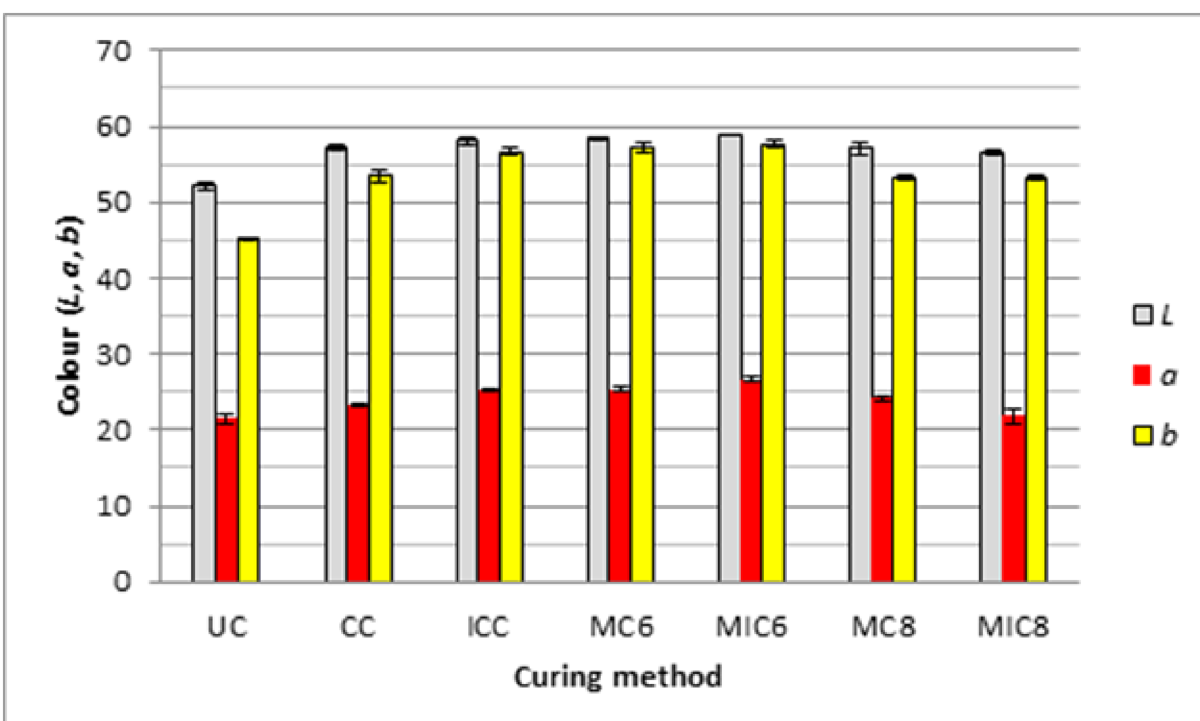

Fig. 1. Effect of different curing methods on colour values of turmeric cv. Suranjana

Table 2. Effect of curing methods on chemical composition dry recovery and drying time of Suranjana cultivar of turmeric

Curing method	Curcumin content (%)	Essential oil content (%)	Total phenolic content (mg GAE 100 g^{-1})	Dry recovery (%)	Drying time (h)
UC	4.31	3.28	590.15	17.77	29.00
CC	4.19	3.33	577.92	19.34	26.00
ICC	4.38	3.58	647.03	19.44	22.84
MC6	4.74	3.62	576.31	24.20	23.00
MIC6	5.20	4.38	554.25	20.94	22.84
MC8	4.52	3.60	459.39	15.77	20.84
MIC8	4.46	3.51	457.40	18.97	21.00
SEm (±)	0.20	0.18	40.08	0.456	0.86
CD at 0.05	0.61	0.54	122.74	1.397	2.64

results in faster heating as the material is heated by volumetric heating method and the curing process is completed in a short time, unlike in conventional method, where heat is transferred slowly from the outer surface to inside. Higher curcumin content in microwave treated turmeric cubes was also observed by Hmar *et al*. (2017). Higher retention of curcumin in curing in alkaline solution was reported by Kumar *et al*. (2000). Presence of alkali at higher temperature might have led to formation of ferulic acid and feruloilmethane (Tonnesen & Karlsen 1985) which can participate in condensation reaction during alkali degradation generating the compounds of yellow to yellow-brownish colour. This may affect the spectrophotometric observation of curcuminoid pigment.

Essential oil content in cured turmeric powder

Essential oil content in turmeric powder in microwave treatment with 0.1% $NaHCO_3$ solution for 6 min (MIC6) was maximum (4.38%) while the lowest (3.28%) was recorded in UC (uncured samples). Gelatinization of starch during curing of turmeric rhizomes might have contributed to better extraction of essential oil, compared to uncured samples. Longer duration of microwave treatment (MC8 and MIC8) reduced the essential oil content. Jayashree & Zachariah (2016) also reported that longer duration of heat treatment (boiling in water or steam cooking) reduced essential oil content.

Total phenolic contents in turmeric powder

Total phenolic content in ethanolic extracts of cured and dried samples were measured by Folin's reagent. The data presented in Table 2 shows that maximum total phenolic content (647.03 mg GAE 100 g^{-1}) was found in turmeric powders prepared by conventional curing with 0.1% $NaHCO_3$ solution for 45 min (ICC) while, minimum (457.39 mg GAE 100 g^{-1}) was found in microwave treatment with 0.1% $NaHCO_3$ solution for 8 min (MIC8). Polyphenoloxidase (PPO) enzyme plays a crucial role in the phenolic content in turmeric samples. More severe heat treatment (generally above 60 ^{o}C) causes inactivation of PPO (Chisari *et al*. 2007), which in turn results in higher availability of the substrates for its action i.e., phenolic content (Prathapan *et al*. 2009; Hirun *et al*. 2014). With increased temperature and time of heat treatment, higher total phenolic content value was also reported by Prathapan *et al*. (2009). This study also reports highest phenolic content in conventional heat treatment method. As the curing process by microwave treatment is completed within 6 min, conventional heating for 45 min might have caused more inactivation of PPO enzyme. Decrease in total phenolic content in the microwave treated samples for 8 min duration (MC8 and MIC8) may have occurred due to nonenzymatic oxidation of polyphenols.

Dry recovery of turmeric

Dry recovery was calculated as the percentage of dried turmeric obtained from fresh rhizomes and presented in Table 2. The highest dry recovery of turmeric rhizomes (24.20%) was observed in MC6 (microwave treatment with water for 6 min) and lowest dry recovery (15.77%) was recorded in MC8 (microwave treatment with water for 8 min). Increasing curing time in different methods (water boiling and steam cooking) has also been reported to result in lesser dry recovery (Jayashree & Zachariah 2016).

Effect of curing methods on the rate of drying of turmeric

Turmeric rhizomes cured by different treatments were dried in hot air oven at 60 °C. Moisture content of the dried rhizomes ranged between 8.65 and 10.25% (w.b.). The average total drying time required in 3 replications in different curing methods is shown in Table 2. Drying time was maximum for uncured rhizomes where it took 29 h to attain a moisture content of 8.66%. Samples from MC8 dried fastest; moisture content reduced to 9.12% in 20.84 h. The variation in drying time required for turmeric rhizomes from different curing treatments was statistically significant.

Change in moisture content of rhizomes from different curing methods has been presented in Fig. 2. Drying rate of turmeric rhizomes (Fig. 3) was calculated as kg/moisture removed/m^2. min from the weight loss of turmeric during drying and surface area of the rhizomes. The slowest rate of drying was observed in uncured rhizomes. Microwave treated samples showed faster drying than conventional cured samples. The rate of drying was much faster in MIC6 (Microwave treatment with 0.1% sodium bicarbonate $NaHCO_3$ solution for 6 min). This may be attributed to the fact that curing for longer duration softens the tissues and thus facilitates movement of moisture inside the rhizomes at a faster rate and reduces drying time. Jayashree & Zachariah (2016) also reported reduction in drying time by boiling in water and steam cooking. However, Surendhar

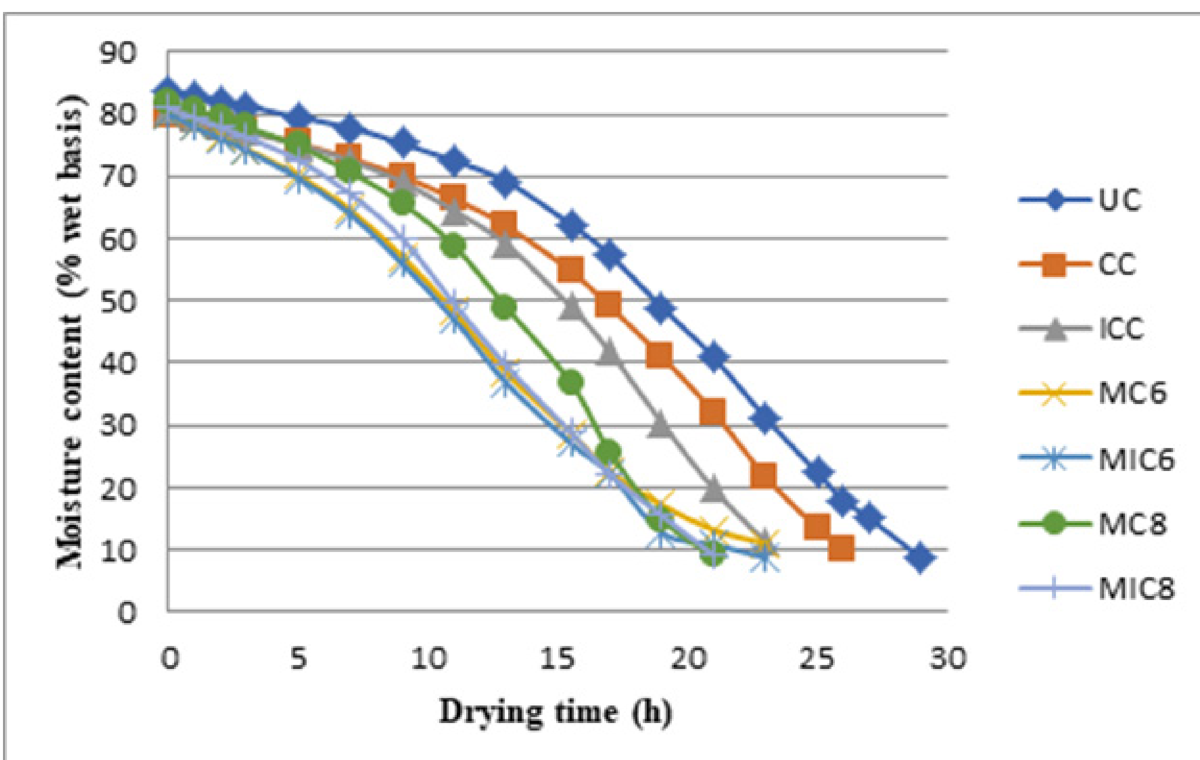

Fig. 2. Change in moisture content with drying time of turmeric rhizomes from different curing methods

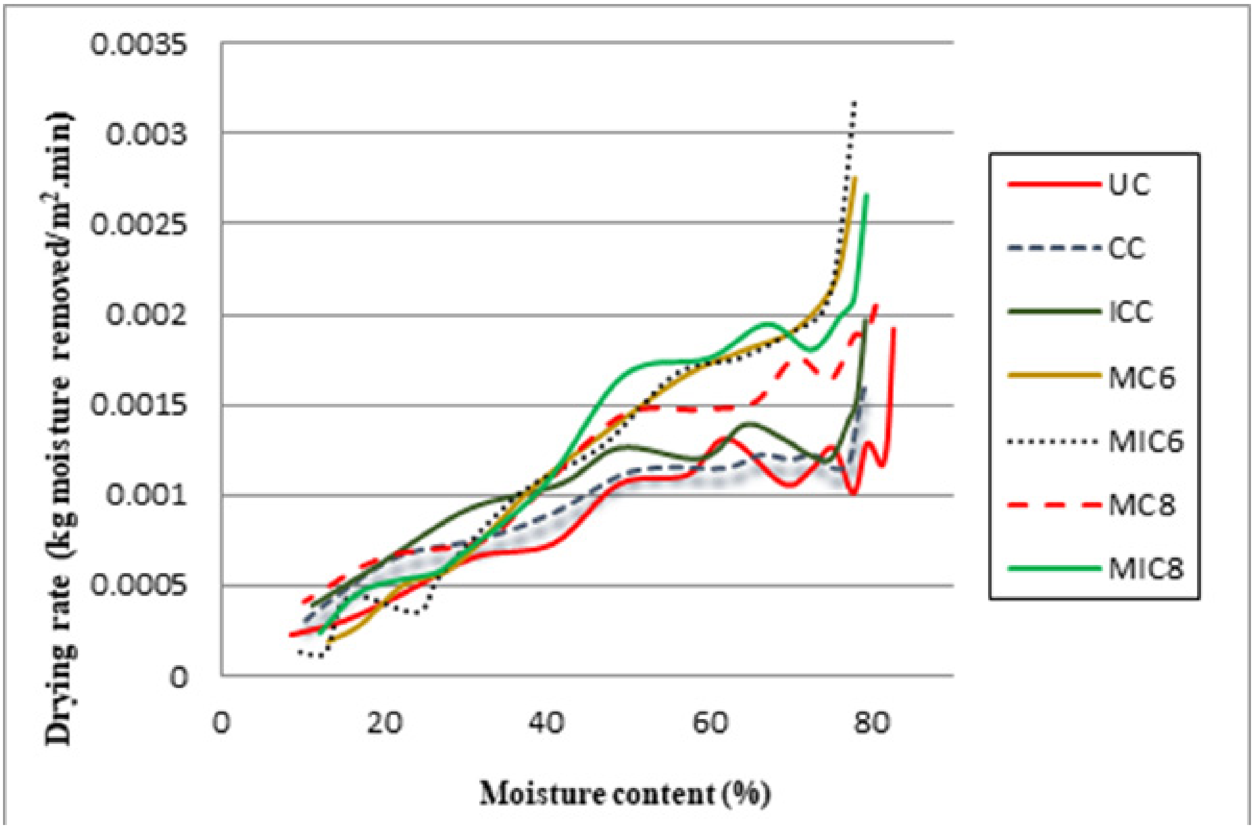

Fig. 3. Change in drying rate of turmeric rhizomes with moisture content during drying

et al. (2018) found negligible variation in drying rate among cured and fresh samples.

It can be observed from Fig. 3 that drying occurred in falling rate period for all the samples. It could be seen that Microwave treated turmeric samples (MC6, MIC6, MC8, MIC8) showed higher drying rate upto 10 h in comparison to conventional cured samples. As the drying progressed the drying rate decreased with time. Due to high amount of surface moisture availability in the initial stage of drying, the drying rates were found to be higher. After some period of drying, the surface becomes dry and drying in falling rate period is governed by the rate of moisture migration from the inside of the material to the surface. Similar pattern of change in drying rate was also reported by Surendhar *et al*. (2018) and Jeevarathinam *et al*. (2021) for microwave drying and infrared assisted hot air drying. Higher degree of tissue softening in microwave treatment and lesser hardness of the rhizomes, might have contributed towards faster moisture movement through the tissue and thus faster drying rate.

Conclusion

Curing methods significantly affect the hardness, colour, chemical composition as well as drying time of turmeric rhizomes. Higher degree of tissue softening by curing treatment results in faster drying due to better moisture movement in the rhizomes. Samples cured in the microwave for 6 min in 0.1% $NaHCO_3$ had the highest curcumin content, essential oil content and colour parameters. This treatment also resulted in fastest drying rate. Longer duration of microwave treatment did not bring desirable changes in turmeric of cultivar Suranjana. Drying of turmeric rhizomes treated by different curing methods occurred fully under falling rate period.

Acknowledgement

Authors acknowledge the support from the Department of Plantation Crops and Processing, and Central Instrumental Centre of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal.

References

Bhat A G, & Hegde R V 2018 Effect of pre-drying treatments and drying methods on drying time, moisture content and dry recovery of turmeric (*Curcuma longa* L.). J. Farm Sci. 31(3): 315–319.

Buggenhout S V, Sila D N, Duvetter T, Loey A V & Hendrickx M 2009 Pectins in processed fruits and vegetables: Part III Texture engineering. Compr. Rev. Food Sci. Food Saf. 8(2): 105–117.

Chisari M, Barbagallo R N & Spagna G 2007 Characterization of polyphenol oxidase and peroxidase and influence on browning of cold stored strawberry fruit. J. of Agric. Food Chem. 55(9): 3469–3476.

Dandekar D V & Gaikar V G 2007 Microwave assisted extraction of curcuminoids from *Curcuma longa*. Sep. Sci. Tech. 37(11): 2669–2690.

Diaz J V, Anthon G E & Barrett D M 2007 Nonenzymatic degradation of citrus pectin and pectate during prolonged heating: Effects of pH, temperature, and degree of methyl esterification. J. Agri. Food Chem. 55(13): 5131–5136.

FAO, 2004 Curcumin, Chemical and Technical Assessment. 61st Joint FAO/WHO Expert Committee on Food Additives (JECFA) Meeting. Pp. 1-8. URL: http://www.fao.org/fileadmin/templates/agns/pdf/jecfa/cta/61/Curcumin.pdf

Farzana W, Ashitha G N, Kuruba E K & Amirtham D 2018 Effect of time and steam pressure on gelatinization of starch and antioxidant properties of curcumin of turmeric (*Curcuma longa*) Rhizomes. Int. J. Econ. Plants. 5(1): 27–31.

Govindarajan V S & Stahl W H 1980 Turmeric chemistry, technology and quality. CRC Critical reviews. Food Sci. Nutr. 12(3): 199–301.

Hmar B Z, Dipsikha K & Brijesh S 2017 Optimization of microwave power and curing time of turmeric rhizome (*Curcuma longa* L.) based on textural degradation. LWT-Food Sci. Technol. 76: 48–56.

Jayaprakasha G K, Rao L J M & Sakariah K K 2002 Improved HPLC method for the determination of curcumin, demethoxycurcumin, and bisdemethoxycurcumin. J. Agric. Food Chem. 50(13): 3668–3672.

Jayashree E & John T Z 2016 Processing of turmeric (*Curcuma longa*) by different curing methods and its effect on quality. Ind. J. Agri. Sci. 86(5): 696–698.

Jeevarathinam G, Pandiselvam R, Pandiarajan T, Preetha P, Balakrishnan M, Thirupathi V & Kothakota A 2021 Infrared assisted hot air dryer for turmeric slices: Effect on drying rate and quality parameters Lebensmittel-Wissenschaft und-Technologie 144 (2): DOI:10.1016/j.lwt.2021.111258.

Kebede B H, Forsido S F, Tola Y B & Astatkie T 2021 Effects of Variety and Curing and Drying Methods on Quality Attributes of Turmeric (*Curcuma domestica*) Powder. Braz. Arch. Biol. Technol. 64: 1–9.

Khanna N 1999 Turmeric-nature's precious gift. Curr. Sci. 76(10): 1351–1356.

Kumar V K, Vadiraj B A, Sivadasan C R & Potty S N 2000 Post-harvest management of turmeric for higher recovery of curcumin, Spices and aromatic plants: challenges and opportunities in the new century. Centennial conference on spices and aromatic plants, Calicut, Kerala, India. 281–283.

Madhusankha G D M P, Thilakarathna R C N, Liyanage T & Navaratne S B 2018 Analysis of curcumin content in Sri Lankan and Indian turmeric rhizomes and investigating its impact on the colour. Int. J. Food Sci. Nutr. 3(4): 3–5.

Mayure A T, Pudagar I P, Pandiarajan T, Amirtham D & Uma D 2018 Effect of curing method on the quality of turmeric rhizomes. Green Farming 9(6): 1050–1054.

Maniglia B C, de Paula R L, Domingos J R D R & Tapia D R 2015 Turmeric dye extraction residue for use in bioactive film production. Optimization of turmeric film plasticized with glycerol. Food Sci. Tech. 64: 1187–1195.

Meng F C, Zhou Y Q, Ren D, Wang R, Wang C, Lin L, Zhang X Q, Ye W C & Zhang Q W 2018 Turmeric: A Review of Its chemical composition, quality control, bioactivity, and pharmaceutical application. Natural and Artificial Flowing Agents and Food Dyes. Pp. 299-350.

Prathapan A, Lukhman M, Arumughan C, Sundaresan A & Raghu K G 2009 Effect of heat treatment on curcuminoid, colour value and total polyphenols of fresh turmeric rhizome. Int. J. Food Sci. Tech. 44(7): 1438–1444.

Reddy I V S 2017 Effects of Cooking and Drying Methods on Curcumin Content of Turmeric. Int. J. Pure App. Biosci. 5(6): 1730–1734.

Roohinejad S, Koubaa M, Barba F J, Leong S Y, Khelfa A, Greiner R & Chemat F 2017 Extraction Methods of Essential Oils from Herbs and Spices. Essential Oils in Food Processing: Chemistry, Safety and Applications. 21–45.

Sangha G S & Mittal T C 2021 Influence of curing parameters on quality and yield of turmeric (*Curcuma longa*). Ind. J. Pure App. Biosci. 9(1): 481–488.

Sila D N, Duvetter Roeck T A D, Verlent I, Smout C & Graham K 2008 Texture changes of processed fruits and vegetables: Potential use of high-pressure processing. Trends Food Sci. Technol. 19(6): 309–319.

Spice Board of India 2021 URL: http://www.indianspices.com/sites/default/files/majorspicewise2021.

Surendhar A, Sivasubramanian V, Vidhyeswari D & Deepanraj B 2019 Energy and exergy analysis, drying kinetics, modeling and quality parameters of microwave-dried turmeric slices. J. Therm. Anal. Calorim. 136 (2): DOI:10.1007/s10973-018-7791-9.

Suresh D, Manjunatha H & Srinivasan K 2007 Effect of heat processing of spices on the concentrations of their bioactive principles: turmeric (*Curcuma longa*), red pepper (*Capsicum annuum*) and black pepper (*Piper nigrum*). J. Food Comp. Anal. 20(3): 346–351.

Thiyagarajan G, Vijayakumar M, Selvaraj P K, Duraisamy V K & Mohamed Yassin M 2011 Performance Evaluation of Fertigation of N and K on Yield and Water Use Efficiency of Turmeric through Drip Irrigation. Int. J. of Bio-resour. Stress Manag. 2(1): 69–71.

Tonnesen H H & Karlsen J 1985 Studies on curcumin and curcuminoids. VI. Kinetics of curcumin degradation in aqueous solution. Lebensmittel Forshung 180(5): 402–404.

Vadivambal R & Jayas D S 2007 Changes in quality of microwave-treated agricultural products: a review. Biochem. Eng. J. 98(1): 1–16.

Velappan E, Thomas K G & Elizabeth K G 1993 New Technologies for on-farm processing of spices. In: Post Harvest Technology of Spices, Proceedings of the National Seminar held at RRL, Trivandrum 1993. Spices Board, Cochin, India.

Venkateshwari T, Ganapathy S, Arulmari R & Vijayakumary P 2021 Effect of drying temperature on the curcumin content of turmeric rhizomes (*Curcuma longa* L.). J. Pharm. Innov. 10(10): 2349–2351.

Weiss E A 2002 Spice Crops. CAB International publishing, Oxon, UK.