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Effect of curing and drying process of turmeric on its quality: A review

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Abstract
Turmeric (*Curcuma longa* L.) is one of the most important spice crops derived from the rhizomes and belongs to the family *Zingiberaceae*. The rhizomes of the plant when dried and ground provide yellow and flavorful powder used for centuries as a natural coloring agent in food cosmetics and textiles as a flavoring compound and also as an insect repellent in Indian medicine. Recently it has been valued worldwide as a functional food due to its health-promoting properties. India is one of the leading countries in the production of raw turmeric and other sub-products related to turmeric. The post-processing of turmeric is usually done 2 or 3 days after harvesting which involves different unit operations such as cleaning, washing, curing (boiling), drying, polishing, grinding, and packaging. Retaining the curcumin content of turmeric is important and depends on the methods used to process the turmeric. This review paper presented information related to the curing and drying methods of turmeric processing. The different methods used to cure and dry the turmeric rhizomes or their slices affect the quality of the final product. In the present study, steam cooking (30 min) for curing while convective drying (50-60 °C) and solar conduction drying (39-51 °C) methods for drying are found to be the most efficient methods with maximum retention of curcumin and oleoresin content.

Keywords: Turmeric, curing, drying, *Curcuma longa*, curcumin

Introduction
Turmeric (*Curcuma longa* L.) is an important spice crop grown in India which is generally used for cooking as well as medicinal purposes. Turmeric is a member of the ginger family (*Zingiberaceae*) and it is also known as the 'Golden Spice of India'. The annual global production of turmeric is around 11 lakh tonnes. India is one of the largest producer, consumer and exporter of turmeric in the world. India accounts for about 80% of the world's turmeric production and 60% of the world's exports [1].

Turmeric rhizomes when dried and ground, provide a yellow and powder with flavour. Normally, turmeric rhizomes are used in the form of dried rhizomes or the form of powder. Recently it has been valued world-wide as a functional food due to its health-promoting properties. Turmeric is generally used as a condiment in vegetable, meat and fish preparations due to its colour and mild flavour. It has long been used as a medicine in Ayurveda and Unani systems for medicine in India. In confectionery and pharmacy, it is used as a safe colouring agent. It is also claimed that the external application of turmeric suppressed unwanted hair growth and is a preventive measure against skin infections [2].

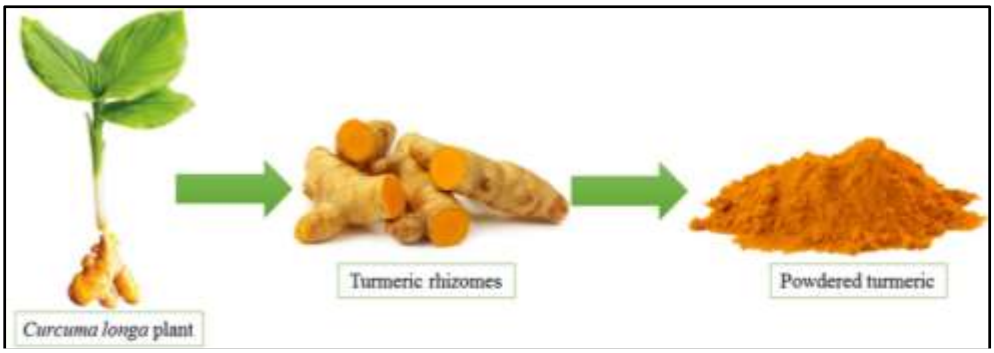

Fig 1: *Curcuma longa* plant, turmeric rhizomes and powdered turmeric [3]

The post-processing of turmeric is generally done after 2 or 3 days after harvesting. Turmeric rhizomes contain initial moisture content of about 70-80% at the time of harvest which should be reduced to a safe limit of moisture content of about 10% for milling and 6% for storage [4]. Turmeric processing involves different unit operations such as cleaning, washing, boiling, drying, polishing, grinding and packaging. Curing or boiling fresh rhizomes is an essential method which promotes the gelatinization of starch and facilitates uniform drying. On the other hand, turmeric followed by non-boiling shows better quality than water-boiled turmeric concerning the curcumin content, oleoresin content and essential oil content [5-6].

The conventional practice of drying turmeric rhizomes as a whole is performed under the sun, which is a time-consuming method, and produces an inferior quality product. A hot air dryer is generally used for drying food materials, but it causes various quality losses such as colour, taste and nutrient content in the product during drying. Mechanical drying helps to overcome all the drawbacks of sun drying [5]. The use of appropriate drying technologies can be helpful to produce a good quality product. The mechanical drying method gives better quality of product and it also avoids the dependency on weather and helps to reduce the microbial contamination of the food product [7].

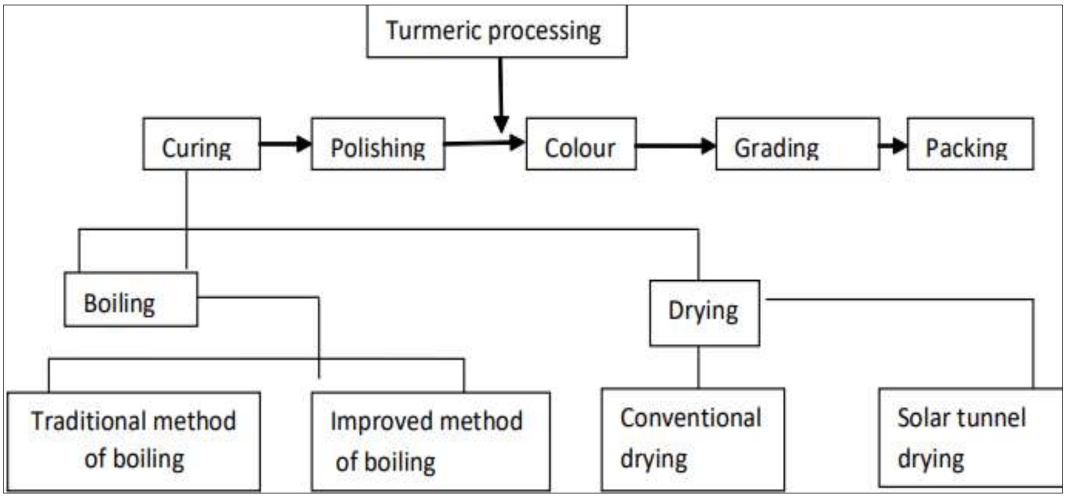

Fig 2: Post-processing of Turmeric using various methods [8]

Post-processing of Turmeric rhizomes

Preliminary process

The post-processing of turmeric is generally done after 2 or 3 days after harvesting [4]. Freshly selected turmeric rhizomes were cleaned and washed thoroughly in tap water to remove the adhering soil, hairs, and extraneous matter. The undesirable portion was removed manually and rhizomes were again washed and cleaned properly. The cleaned rhizomes of the turmeric are then used for further turmeric processing.

Fig 3: Fresh turmeric rhizomes

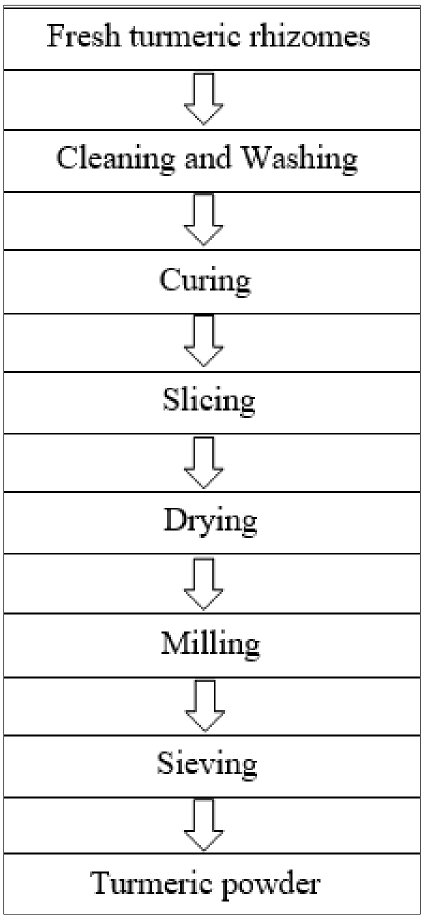

Fig 4: General process flow chart for turmeric processing

Curing or boiling of turmeric rhizomes

Curing or boiling is the first post-harvest operation performed at the farm level where the fresh rhizomes are boiled in water until soft before drying. Boiling destroys the vitality of fresh rhizomes, avoids the raw smell, shortens the drying time and gives a product with a uniform colour. In the traditional method, a vessel made of galvanized iron is used to cook turmeric. An improved turmeric boiler using steam boiling technique were followed when large quantities of turmeric are to be cured. An overcooking and undercooking were found to affect the quality of turmeric rhizomes [8]. Boiling time affect the main curcumin content of turmeric rhizome, it is decreases with increase in boiling time. To handle the large quantities of turmeric rhizome a several improvements is made in heating furnace and cooking vessels. One more advantage of boiling is that microbiological activity is significantly reduced [9].

Drying

Drying is one of the most important methods of preservation and production of a wide variety of products and was a major aim to prolong its storage life. Generally, the drying mechanism involves two simultaneous processes, energy transfer and mass. Energy transfer can be conductive, convective, radioactive or any combination of these three. Mass transfer includes the removal of moisture that moves from the interior of the dried material toward the surface under the capillary forces, liquid diffusion due to concentration gradients, surface diffusion and water vapour diffusion in pores filled with air, flow due to pressure gradient as driving force and flow owing to a vaporisation-condensation system [10].

The complete drying process can be divided in three stages. In the first stage of drying only free moisture at the surface is removed so the drying rate is constant. This is called the "constant rate drying period". At the end of this period, dry spots appear on the surface of the material and the drying rate decreases. This is the beginning of the "first falling rate period" (Fig. 5). Once the surface is completely dried, moisture is transported from inside of the product to the surface by capillary action. The third drying period is called "the second falling rate" and the drying rate is lower than the previous one [11].

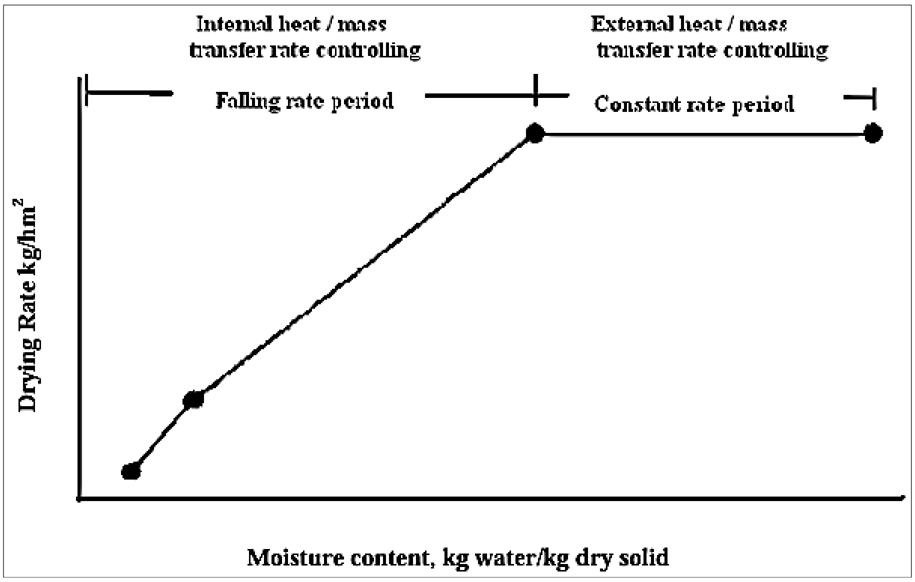

Fig 5: Typical drying rate curves under constant drying conditions [12]

Several types of dryers and drying methods have to be developed and adopted for fruits and vegetables with specific situation and commercial application. These dryers can be divided, considering many factors, such as pressure (Atmospheric and sub atmospheric), type of unit operation (continuous, batch and semi continuous), the temperature (freeze drying and hot air convective drying) etc. The main advantages in drying of fruits and vegetable are as follows [13].

1. Enhanced shelf life is high because of inhibition of microbial and enzymatic reaction.
2. Substantially lower costs of handling, transportation and storage.
3. Minerals and calorie providing constituents remain practically unaffected
4. Provides consistent product as seasonal variations are diminished.
5. Dried fruits are packed in recyclable packages; but not always done with fresh fruits.

In the post-processing of turmeric, after the curing process, the drying of turmeric rhizomes or slices was carried out by using various drying methods.

Polishing

The rhizome with rough surface and with poor surface colour is polished to obtain the better surface finish. Polishing can be done either by mechanically or by manually. In case of mechanical polishing the mechanical drum is used, whereas in case of manual polishing rhizome is placed in bags and rubbed with the help of stones. iv. Grinding and packaging

Grinding and packaging

Before grinding the turmeric rhizome, it is need to clean the rhizome. After cleaning the rhizome is grinded to a fine powder. Packaging can be done by manually or by automatic machine. Packing of turmeric is done in different size depending on the customer requirement.

Literature Review

Curing or boiling of turmeric rhizomes

Suresh *et al.* studied the heat treatments of turmeric, red pepper and black pepper by: (i) boiling for 10 min, (ii) boiling for 20 min and (iii) pressure cooking for 10 min. It was observed that the significant loss of active constituent of spices was subjected to heat processing. Curcumin loss due to heat processing in turmeric was 12.1-18.8 mg/g, with maximum loss in pressure cooking for 10 min [14].

Kamble and Soni conducted a study to improve the traditional turmeric boiling pot and reduce the losses in quality, time and fuel in turmeric processing. A study was conducted for different turmeric varieties such as Rajapuri, Krishna, Salem, Tekurpetha and followed by boiling in a traditional open pan and improved boiling pot. They found that the turmeric boiled (35 minutes) in an improved boiling pot retained 3.33% essential oils and 2.30% curcumin as against 2.93% and 2.57%, respectively in a traditional boiling pot [15].

Shinde *et al.* optimized the process in turmeric heat treatment by design and fabrication of a blancher. They studied the processing of turmeric by traditional and steam blanching methods. It was observed that in the steam cooking process, fuel requirement was less than half of the traditional method. The loss of colour observed in curcumin was 1.5 to 2.5% in steam cooking, whereas 1.6 to 3.5% was found in boiling. They concluded that the process of steam treatment is beneficial to farmers and turmeric process industries [16].

Lokhande *et al.* studied the effect of curing and drying methods on the recovery of curcumin content and essential oil content in different turmeric cultivars. The Krishna cultivars were best among the three cultivars on the basis of physico-chemical analysis whereas, Salem and Tekurpeta had higher values for colour. The fingers cured with improved method loose moisture at faster rate than uncured and cured with traditional method. The fingers of Salem cultivar cured with improved method followed by shade-net drying had got higher recovery. The essential oil content of three cultivars was unaffected by the curing and drying methods [17].

Patil and Chhapkhane studied the large-scale of turmeric boiling by the use of conventional plants with multiple cooker and boiler assembly placed on trolley. The plant is provided with the furnace, condensate extraction mechanism, packed pressure vessels and mobile plant. In traditional plants, the boiling is done without maintaining the pressure in the vessel, so the boiling is inefficient. The efficiency of the actual processing plant is 13.19% which is very less. The losses are very hard to control in a minimum cost. So the objectives of this project were to reduce cooking time, fuel consumption, heat losses, reduce labor effort and cost, and recycle condensate [18].

Gagare *et al.* conducted a study on standardization of curing and microwave drying of turmeric (*Curcuma longa* L.) rhizomes. Curing and drying are important unit operations in turmeric processing for the production of good-quality products. Optimization of the process parameters for curing and microwave drying of turmeric is the need of hour for quality production of dried turmeric. These parameters were optimized by conducting trials for curing (boiling in 0.1% sodium carbonate solution for 15, 30 and 45 min) and microwave drying (Power levels of 1, 1.5 and 2 kW). The cured as well as dried rhizomes were evaluated for quality parameters. The optimum boiling time for curing and power level for microwave drying of turmeric rhizomes was found to be 30 min and 1.5 kW for quality production [19].

Jayashree and Zhachariah studied the processing of turmeric by different curing methods and its effect on quality. The results of the study on curing Prathiba variety turmeric by different curing methods indicated that slicing significantly reduced the drying time up to 9 days. Turmeric cured by boiling water for 40, 60, 90 min, took 11 days, while turmeric rhizomes cured by steam cooking for 30, 45 and 60 min, took 24, 23 and 12 days for complete drying. An increase in curing time of turmeric rhizomes resulted in significant reduction in curcumin, starch, essential oil and oleoresin content. The maximum retention of curcumin (5.91%) and essential oil (3.6%) was obtained for rhizomes cured for 40 min in Water boiling method, while the maximum retention curcumin (6%), essential oil (3.33%), oleoresin content (13.96%) was obtained for rhizomes steamed for 30 min in steam cooking. They concluded that, the steam cooking had several advantages over traditional cooking by water boiling in terms of fuel consumption and the quantity of rhizomes [20].

Dhawle *et al.* studied various conventional and improved methods for the processing of turmeric rhizomes. It was found that the rhizomes boiled conventionally in water retain less curcumin content and essential oil. They also observed that there was no engineering and thermal background in designing of conventional turmeric boiling system due to this system was very bulky and there was a large amount of heat loss. It was noticed that the time required for turmeric processing was also more in the conventional system. It was concluded that the essential constituent of turmeric i.e. curcumin content was retained at a higher value in the improved system as compared to the conventional system [9].

Kebede *et al.* conducted the study to determine the effects of variety (Bonga51/71, HT3/2002, and Dame), Curing methods [Conventional curing method (CCM) and improved curing method (ICM)], and Drying methods [open-air drying (OSD), solar tunnel dryer (STD), and greenhouse solar dryer (GSD)] on the quality attributes (moisture content, curcumin, oleoresin, essential oil, and colour) of turmeric powder. The maximum retention of curcumin (6.99%) and oleoresin (13.88%) were foundin Bonga51/71 variety cured with CCM and dried with STD, and Dame variety cured with ICM and dried with OSD, respectively. On the other hand, the highest (6.52%) essential oil yield was obtained from Bonga51/71 variety cured with CCM and dried with OSD. The results showed that, STD is the best dryer to reduce the moisture content of turmeric to the required level in a short period, irrespective of curing method. It also concluded that the processing of turmeric in CCM and STD retains the maximum curcumin content of Bong51/71 and Dame varieties [21].

Drying of turmeric rhizomes

Jose and Joy conducted study on solar tunnel drying of turmeric (*Curcuma longa* L.) for quality improvement. They collect freshly harvested turmeric rhizomes from 30 stations and drying experiments were conducted by adopting various methods such as solar tunnel drying, conventional drying, and commercial drying. It was observed that the conventional processing maintained the quality of turmeric. It was concluded that solar tunnel drying was an effective method as compared to traditional open sun drying, in which retention of curcumin, volatile oil and oleoresin was high, with less drying time [22].

Singh *et al.* studied the effect of mechanical drying air conditions on the quality of turmeric powder. The mother and finger rhizomes of the Suvarna variety of turmeric were boiled separately in an open pan for 45 min at 100 °C and dried in a tray dryer at drying air temperatures of 45, 50, 55, 60 and 65°C with drying air velocities of 1, 2 and 3 m/s to approximately 10% (wb) moisture content. The polishing of rhizomes was done manually and powdered. It was observed that the change in colour (ΔE) with drying time and the values found to be 2.3 and 2.7 for fingers and mothers, respectively at 60°C and 2 m/sec air velocity. It was reported that the oleoresin content was 13.0 and 12.0% for fingers and mothers, respectively. It was concluded that the best quality turmeric was obtained by drying at 60°C drying air temperature and 2 m/s air velocity [4].

Saetan *et al.* conducted study on turmeric drying using a combined vacuum and far-infrared dryer. The experiment was carried out with following conditions: absolute pressure of 2 and 5 kPa, drying air temperatures of 50, 60, and 70 °C and thickness of turmeric slices 2 and 3 mm. It was observed that curcumin content of dried turmeric sample decreased with an increase in drying temperature, absolute pressure and slice thickness of sample. The curcumin content of the dried turmeric slices of thickness 2 mm found to higher (48.11 mg/g) than other. It was concluded that, drying temperature and slice thickness had significant effects on drying kinetics and quality of the turmeric sample [23].

Bezbaruah and Hazarika studied the generalization of temperature and thickness effects in kinetic studies of turmeric (*Curcuma longa*) slices drying. The drying of turmeric was carried out at a laboratory scale tray dryer at different drying temperatures (40-70 °C) for different slice thicknesses (3-10 mm) and obtained the drying data from the experiments. It was concluded that the faster drying kinetics was established at higher drying air temperatures and also at a lower slice thickness of the samples [24].

Borah *et al.* studied the performance of drying turmeric in a solar conduction dryer (SCD). It was found that the drying air temperature was around 39-51 °C for an ambient temperature in the range of 25-28 °C. The moisture content of turmeric was reduced from 78.65% to 6.36% and 5.50% for solid and sliced samples, respectively in 12 h effective drying time. It was shown that the drying curve of sliced samples was more uniform falling in comparison to that of whole samples and the effective moisture diffusivities were found to be 1.852×10^{-10} and 1.456×10^{-10} for sliced and whole samples, respectively. It was concluded that the drying of sliced rhizomes showed better drying kinetics and reduced drying time as compared to drying in the whole form [25]. Sahu studied different turmeric processing methods to standardize the process treatment.

It was observed that in all the pre-treated samples with different sodium bicarbonate percentages (0.05, 0.1 and 0.2) and boiling time (15, 30 and 45 min), the drying time reduced (99 to 32 h) with an increase in drying air temperature (50 to 70 °C). In the case of non-boiled cut samples (1, 2 and 3 cm) and vacuum treated samples, drying time was reduced with an increase in drying air temperature and a decrease in slice thicknesses (3 to 1 cm). It was also reported that the moisture diffusivity increased with an increase in drying air temperature and the values were found to be 2.22×10^{-10} to 4.12×10^{-10} m^2/s for all the samples. It was stated that all samples have a lower water activity value than 0.65. It was concluded that the curcumin content and oleoresin content were reduced with an increase in drying air temperature [26].

Gan *et al.* studied the effect of drying and blanching on the retention of bioactive compounds in ginger and turmeric. It was found that due to the short drying time, 60 °C was the optimal drying temperature to retain 6-gingerol. However, the changing temperature conditions significantly improved the retention of 6-gingerol. As for blanching, it had a significant negative effect on 6-gingerol retention. Drying was performed under constant conditions at 38 °C, 48 °C, 57 °C and 64 °C and with a relative humidity of 20% and 40%. Drying at 57 °C with a lower relative humidity was the best drying treatment, yielding the highest amount of curcumin among non-blanched samples. It was concluded that blanching for 15 min exhibited the highest curcumin yield while blanching for 5 min and 30 min did not have much effect [27].

Pradeep *et al.* studied the effect of blanching and drying methods on the quality characteristics of fresh turmeric rhizomes. The turmeric rhizomes were dried using various drying methods to get better quality and colour turmeric powder. Sun drying normal [SDN, 30-37 °C and 30-35% relative humidity (RH)], sun drying coupled with the black surface (SDB, 38-60 °C and 28-31% RH), hot air (HA, 50±2 °C and 58-63% RH), and low humidity air (LHA, 50 °C and 28-30% RH) were explored for their drying efficiency of turmeric rhizomes. It was revealed that the curcumin content in higher in unblanched slices of turmeric dried under mechanical drying followed by sun drying coupled with a black surface [6].

Gagare *et al.* conducted an experimental trial on convective drying of turmeric (*Curcuma longa* L.) rhizomes. Turmeric rhizome samples were cured for 30 min in a 0.1% solution of sodium carbonate and dried in a laboratory tray dryer at air temperatures of 50, 60 and 70 °C with a drying air velocity of 2 m/s. It optimized the drying air temperature based on maximum retention of curcumin content, and b value of colour with minimum drying time and specific energy consumption. It was concluded that for convective drying of turmeric rhizomes, the optimum drying air temperature was found to be 60°C with a drying time of 29 hours [7].

Table 1: Moisture diffusivity and quality attributes at different drying temperatures [7]

Drying method	Drying temperature (°C)	Moisture diffusivity	R^2	Curcumin content (%)	Colour b^* value	Drying time (h)
Convective tray drying	50	3.22×10^{-10}	0.970	2.96	42.91	36
	60	3.41×10^{-10}	0.976	2.92	44.91	29
	70	4.12×10^{-10}	0.987	2.80	40.21	26

Bhat and Hedge studied the effect of pre-drying treatments and drying methods on drying time, moisture content and dry recovery of turmeric (*Curcuma longa* L.). The investigation deals with five pre-drying treatments namely, slicing, peeling, steaming, blanching with polythene sheet and boiling with three drying methods namely, solar drying, microwave drying and open sun drying. It was found that among pre-drying treatments, steaming reported the lowest drying time, and the lowest final moisture content and blanching with polythene sheet reported the highest dry recovery. It was also revealed that among the various drying methods, microwave drying recorded the least drying time and the highest dry recovery and solar drying recorded the lowest final moisture content [28].

Joseph *et al.* evaluated different methods for drying turmeric and extraction of curcumin. The drying of turmeric rhizomes is carried out using an air dryer (60-100 °C) and solar conduction dryer (39-51 °C). It was observed that the drying time reduced (6.5 to 1.5 h) with the increase in drying air temperature (60 to 100 °C) using an air dryer. The time required to dry turmeric rhizomes using a solar conduction dryer was 12 h. It was concluded from the results that, solar conduction drying was a more energy-efficient process for drying turmeric rhizomes, but the drying time was much higher than that of air drying [29].

Pisalkar *et al.* conducted study on convective drying process for turmeric rhizomes. The fresh turmeric rhizomes were collected and pre-treated with various methods such as blanching (20 min), curing (45 min in 0.1% sodium bicarbonate solution) and non-treated samples sliced into 10 mm thickness. The samples were mechanically dried at drying air temperatures of 50, 60 and 70 °C with constant air velocity (1 m/s). It was observed that the values of curcumin content, oleoresin content and water activity for all the samples ranged from 2.04 to 2.95%, 3.39 to 4.85% and 0.59 to 0.64, respectively. From the results of convective drying, it was concluded that the drying time was reduced with an increase in drying air temperature [30].

Raza *et al.* studied the effect of different drying treatments on the concentration of curcumin in raw *Curcuma longa* L. During conventional processing of turmeric, the raw turmeric rhizomes were boiled and dried under direct sunlight for 1-4 hrs. and 25-30 days, respectively. It was observed that the effect of different drying treatments including shade, direct sunlight, solar dryer, convection oven and hot-air drying on the concentration of curcumin. The results showed that the non-boiled turmeric rhizomes took too much time to reach the final moisture content below 10% in all drying treatments which was not economically feasible and hygienic. It was concluded that the optimum drying conditions for turmeric rhizomes drying were 1 h boiling and drying at 70 °C in the hot-air dryer [31].

Abioye *et al.* studied the influence of hot air on the drying kinetics of turmeric slices. The turmeric slices (3 mm, 5 mm and 7mm) were dried in a laboratory oven dryer at 40, 50 and 60 °C drying air temperature. It was observed that the drying time varied in the range from 420 to 1020 min, 540 to 1080 min and 660 to 1140 min with an increase in drying air temperature from 40 to 60 °C. It was reported that the effective moisture diffusivity coefficient increased with increasing drying air temperature. The effective moisture diffusivities varied from 1.35×10^{-10} to 5.00×10^{-10} m^2/s, 3.00×10^{-10} to 10.91×10^{-10} m^2/s and 4.56×10^{-10} to 13.00×10^{-10} m^2/s at 40, 50 and 60 °C, respectively. It was concluded that the turmeric slices of 3 mm had shorter drying time and higher drying rate as compared to other slices [32].

Table 2: Comparative drying data of various methods of drying for turmeric

Drying Method	Optimized Drying temperature (°C)	Pre-treatment	Sample type	Time required (hr)	Curcumin (%)	Reference
Convective tray drying	60	Non-curing	Slice	8	4.35	[5]
Hot air drying	55	Non-curing	Slice	8	4.6	[6]
Convective tray drying	60	Curing (30 min)	Solid	29	2.92	[7]
Convective tray drying	60	Curing (40 min)	Slice	6	5.04	[17]
Convective tray drying	55	Curing (30 min)	Slice	8	-	[24]
Solar conduction dryer	39-51	Blanching (2 min)	Slice	12	1.60 – 5.70	[25]
Solar conduction drying	39-51	-	Slice	12	-	[29]

Effect of curing and drying on turmeric powder

Lokhande *et al.* studied the effect of curing and drying methods on the recovery, curcumin content and essential oil content in different turmeric cultivars. It was revealed that among the three cultivars, Krishna was the best based on physicochemical analysis whereas, Salem and Tekurpeta recorded higher values for colour. It was observed that the fingers of Salem variety cured with improved method dried under shade-net had higher recovery. It was reported that the range of curcumin content varied from 4.95 to 5.18% that of Krishna and Tekurpetha were 2.60 to 2.96% as given in Table 3 [17].

Table 3: Effect of curing and drying methods on curcumin content (%) of turmeric cultivers

Drying method	Salem			Krishna			Tekurpetha		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
Sun drying	4.98	5.02	5.15	2.55	2.60	2.70	2.74	2.80	2.86
Shade-netdrying	5.05	5.13	5.18	2.66	2.84	2.96	2.81	2.84	2.92
Cabinet drying	4.95	5.04	5.12	2.61	2.75	2.91	2.79	2.80	2.86
SE	0.030	0.034	0.017	0.032	0.070	0.080	0.021	0.013	0.020
CD at 5%	0.127	0.147	0.074	0.137	0.301	0.343	0.090	0.057	0.086

T_1 = untreated, T_2 = cured with traditional method and T_3 = cured with improved methods

Ikpeama *et al.* studied the nutritional composition of turmeric (*Curcuma longa* L.) and its antimicrobial properties. The turmeric rhizomes were steamed (10 min) and dried using an oven at a drying air temperature of 65 ˚C It was observed that the turmeric contains moisture content (8.92%), ash (2.85%), protein (9.42%), crude fiber (4.60%) and crude fat (6.85%) [33].

Nisar *et al.* estimated the proximate and total phenolic contents of turmeric (*Curcuma longa* L.). The turmeric rhizomes were steamed (10 min), cut into slices and dried at

40 °C using an oven. It was reported that the values of proximate composition of turmeric such as moisture (13.02%), protein (6.47%), crude fat (5.33%), crude fiber (4.80%), ash (3.49%) and carbohydrates (69.89%) [34].

Jayashree and Zachariah conducted study on processing of turmeric (*Curcuma longa* L.) by different curing methods and its effect on quality. The turmeric rhizomes of the Prathibha variety were cured with eight different methods showing that the slicing significantly reduced the drying time to 9 days. It was observed that as the curing time increased from 30 to 60 min there was a significant reduction in all the quality parameters. It was reported that in the case of slicing, the values of quality parameters like curcumin, essential oil and oleoresin were found to be 5.71%, 3.07% and 12.76%, respectively [20].

Oke *et al.* optimized the proximate compositions of turmeric (*Curcuma longa* L.) rhizome drying in a tray dryer. The fresh turmeric rhizomes were dried using an oven dryer at various temperatures. They analyzed the effect of variables using a three-factor Box-Behnken design, drying air temperatures of 40-65 °C, air velocity (1.5-3 m/s), and drying time (30-240 minutes) on the responses of moisture, fats, protein, fiber content, carbohydrate. They observed that the optimum drying conditions such as 60.14°C drying air temperature, 3 hours drying time and 2.0 m/s air velocity. It was found that the average values of moisture content, ash, fat, crude fiber, crude protein, dry matter, nitrogen, and carbohydrate were 8.82%, 4.63%, 7.91%, 4.61%, 10.68%, 91.94%, 1.90%, 78.88%, respectively. It was concluded that the drying of turmeric rhizome had little effect on the nutritional properties [35].

Nithya *et al.* analysed the effect of slicing, boiling, and drying methods on the extraction of curcumin, oleoresin, and essential oil content of ground turmeric. For the study, various parameters were used like slice thickness of 2 mm and 3 mm, and boiling methods such as pressure boiling at 0.25, 0.5, 0.75 and 1 kg/cm^2. The sample was dried using various drying methods such as tray drying, microwave drying and vacuum drying with the water-boiled and sun-dried whole rhizomes were kept as a control. The control samples showed average curcumin content, oleoresin content and essential oil content values were 3.31%, 6.37% and 2.33%, respectively. The highest curcumin content was observed at 4.35% in un-boiled vacuum-dried turmeric and the lowest curcumin content was observed at 2.34% in pressure boiled and microwave-dried turmeric. The study revealed that the un-boiled turmeric samples showed better quality turmeric powder, as well as the mechanical drying method, gives better quality turmeric than sun-dried turmeric [5].

Sunday *et al.* conducted the study on effect of drying temperature on the proximate and mineral composition of turmeric. The sliced turmeric samples were dried at room temperature, 40, 50 and 60 °C drying air temperatures. It was observed that the crude protein, crude fat and ash content were increased at 50 °C, whereas the crude fat and carbohydrate increased at 60 °C as compared to room temperature and 40 °C. The values of protein content, crude fat, crude fiber, ash, moisture and carbohydrates were given in the Table. 4 for different temperatures. It was concluded that the concentration of the nutrients may be affected by drying air temperature [36].

Table 4: Proximate analysis of Turmeric (*Curcuma longa* L.) rhizomes for different drying air temperatures

Properties	Room Temperature	40 °C	50 °C	60 °C
Crude protein	9.93±0.04	9.64±0.06	9.43±0.04	9.33±0.06
Crude fat	3.13±0.01	3.08±0.01	3.26±0.01	3.21±0.01
Crude fiber	8.29±0.02	8.24±0.02	8.39±0.03	8.33±0.02
Ash	6.71±0.03	6.61±0.03	7.01±0.03	6.90±0.03
Moisture	10.91±0.00	10.64±0.03	9.73±0.02	9.54±0.04
Carbohydrates	61.80±0.02	61.84±0.01	61.88±0.01	62.19±0.03

Conclusion

The study concluded that many researchers worked on conventional and improved methods of turmeric processing followed by drying process to get better quality turmeric powder. The steam cooking (30 min) method was found to be suitable for curing and it reduces the loss of curcumin and consumes less fuel as compared to the water-boiling method. For the drying of turmeric rhizomes, convective drying (50-60 °C) and solar conduction drying (39-51 °C) methods were reported to be best. It was also reported that drying turmeric rhizome slices instead of whole rhizomes helps to reduce drying time with the retention of curcumin and oleoresin content. This article presents various literatures, each with an independent and dependent parameter that has a direct impact on the final product.

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