

DRYING OF TURMERIC (*Curcuma longa*) IN SOLAR TUNNEL DRYER

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**DRYING OF TURMERIC (*Curcuma longa*) IN
SOLAR TUNNEL DRYER**

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DEDICATION

To my guru

*Who guide me, who love me, who care me
and continuously showering blessing over me.*

To my parents

*The reason for what I become today.
Thanks for your great support and continuous care.*

To my true friends

*I am really grateful to you.
You have been my inspiration.*

To my respected guide

*Who is the continuous Source of
Inspiration and constant encouragement for me.*

— **PRADEEP PATIDAR**



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TUNNEL DRYER**

ABSTRACT

Keywords: Turmeric, drying, drying characteristics, solar tunnel dryer, cost economics, physicochemical properties, curcumin, total oil, volatile oil

India, renowned as the "Land of Spices," holds a prominent position as the world's leading producer, consumer, and exporter of spices. Derived from the rhizomes of *Curcuma longa*, a member of the ginger family, turmeric contains bioactive such as curcuminoids, phenolic acids, and flavonoids, all contributing to its health-promoting properties. To preserve turmeric, drying is a time-tested method, aimed at reducing its moisture content from the initial 70-80% at harvest to a safe 10%. Traditional sun drying, while effective, has limitations including extended drying times, space requirements, and potential product quality loss. In response, Solar dryers, which utilize solar radiation as an energy source for drying agricultural products, have been widely implemented in tropical and subtropical regions due to their affordability and cost-effectiveness

This study, conducted during the academic year 2022-2023, focuses on evaluating the drying characteristics of fresh turmeric rhizomes using different blanching temperatures, durations, and slice thicknesses. Both solar tunnel dryers and sun drying methods were employed. Turmeric samples, whole and sliced, were subjected to blanching at varying temperatures (70°C, 80°C and 90°C), durations (15,

30 and 45 minutes), and thicknesses (4 mm, 5 mm and whole). The experimental layout followed a Factorial Completely Randomized Design (FCRD).

The samples were subsequently subjected to drying in two distinct systems, namely, sun drying and solar tunnel drying. The size of drying tray was kept 700 mm x 700 mm x 50 mm with net volume of 0.0245 m³. Spread density of turmeric 214.3 kg/m³ was employed

The specimens are uniformly arranged on the drying layer, maintaining a thickness within the range of 2-3 cm. The drying process was conducted during the daytime, i.e., from 8 a.m. to 6 p.m.

The mean values of physical properties of fresh turmeric viz., moisture content, size, sphericity, bulk density, true density, porosity was 78.25 ± 0.703 % (wb), 30.80 ± 4.82 mm, 0.48 ± 0.07 , 447.87 ± 10.61 kg/m³, 1115.67 ± 39.97 kg/m³, and 60.22 %.

The mean values of proximate composition, viz., total carbohydrate, true protein, total oil and total ash of raw turmeric rhizomes were found to be 9.18 ± 0.38 %, 1.41 ± 0.08 %, 0.82 ± 0.11 % and 0.71 ± 0.18 %, respectively.

The mean value of moisture content, size, sphericity, bulk density, true density and porosity of dried turmeric rhizomes were found to be 9.88 ± 0.57 % (wb), 16.56 ± 2.81 mm, 0.41 ± 0.02 %, 579.15 ± 20.60 kg/m³, 1258.15 ± 61.82 kg/m³ and 54.40 %, respectively.

The highest amount of curcumin (4.18 %), volatile oil (4.00 %), total carbohydrate (63.41 %), total oil (4.90 %) and total ash (8.57 %) was observed in whole turmeric rhizomes dried by solar tunnel drying. The findings viable option that whole turmeric rhizomes with blanching low temperature and time interval and dried by solar tunnel dryer is viable option for good qualities in term of curcumin, volatile oil, total carbohydrate, total oil and total ash than the other drying methods.

From the present investigation, on the basis of biochemical parameters it is concluded that the best quality turmeric powder is prepared by solar tunnel dried whole turmeric rhizomes blanched at 70°C for 15 min.

The recovery level of dried turmeric rhizomes was higher in the Solar Tunnel Dryer (22.40 kg/q) as compared to traditional sun drying method (20.70 kg/q) in terms of quantity as 1.70 kg/q and in terms economics return as Rs. 561.00 per 100 kg of turmeric rhizomes. In other words, producer of Saurashtra region will gain additional benefits of Rs. 2805 per batch of 500 kg of fresh turmeric rhizomes by adopting solar tunnel dryer.

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CERTIFICATE – I

This is to certify that the thesis entitled “**DRYING OF TURMERIC (*Curcuma longa*) IN SOLAR TUNNEL DRYER**” submitted by **PRADEEP PATIDAR (Reg. No. 2050221010)** in partial fulfilment of the requirements for the award of the degree of **Master of Technology (Agricultural Engineering)** in the subject of **PROCESSING AND FOOD ENGINEERING** to the Junagadh Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree or other similar title. The candidate had fulfilled all prescribed requirements. The assistance and help received during the investigation have been fully acknowledged. He has successfully completed the comprehensive/preliminary examination held on **June 12, 2023** as required under the regulation for post-graduate studies. He has submitted kachha bound thesis on **September 22, 2023**.

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Date: 28/11/2023

This is to certify that the thesis entitled “**DRYING OF TURMERIC (*Curcuma longa*) IN SOLAR TUNNEL DRYER**” submitted by **PRADEEP PATIDAR (Reg. No. 2050221010)** to Junagadh Agricultural University, Junagadh in partial fulfillment of the requirements for award of the degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)** in the subject of **PROCESSING AND FOOD ENGINEERING** after recommendation by the external examiners were defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination was satisfactory. We, therefore, forward with recommendation.

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Place: Junagadh
Date: / /2023

(Pradeep Patidar)

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LIST OF ABBREVIATIONS

| | | |
|--------------------------------|---|---|
| Anon. | : | Anonymous |
| ANOVA | : | Analysis of variance |
| AOAC | : | Association of Official Analytical Chemists |
| B. Tech | : | Bachelor of Technology |
| CCRD | : | Factorial Completely Randomized Design |
| CD | : | Critical difference |
| cm | : | Centimetre |
| cm ³ | : | Centimetre cube |
| CRD | : | Completely Randomized Design |
| CV | : | Coefficient of variance |
| DNPH | : | 2, 4 - Dinitrophenylhydrazine |
| <i>et al.</i> | : | et alia (and others) |
| <i>etc.</i> | : | Etcetera (and the rest) |
| Fig. | : | Figure |
| g | : | Gram |
| g/100 g | : | Gram per hundred gram |
| g/cc or g/cm ³ | : | Gram per cubic centimeter |
| GC-MS | : | Gas chromatography-mass spectrometry |
| GDP | : | Gross Domestic Product |
| g/kg | : | Gram per kilogram |
| g/ml | : | Gram per milliliter |
| GMS | : | Glycerol monostearate |
| h | : | Hour |
| H ₂ SO ₄ | : | Hydrogen disulfide |
| <i>i.e.</i> | : | That is |
| kcal | : | Kilocalorie |
| kg/m ² h | : | Kilogram per meter square hour |
| kJ/mol | : | Kilo joule per mole |
| Ltd. | : | Limited |
| m ² | : | Meter square |
| m ² /s | : | Meter square per second |
| m ³ /min | : | Meter cube per minute |

| | | |
|---|---|-----------------------------|
| MC | : | Methylcellulose |
| mg | : | Milligram |
| mg/100 g | : | Milligram per hundred gram |
| mg/g | : | Milligram per gram |
| min | : | Minute |
| ml | : | Millilitre |
| mm | : | Millimetre |
| MR | : | Moisture ratio |
| m/s | : | Meter per second |
| MT | : | Million tonne |
| M. Tech | : | Master of Technology |
| Na ₂ S ₂ O ₅ | : | Sodium meta bisulfite |
| nm | : | Nanometer |
| No. | : | Number |
| NS | : | Non-significant |
| OD | : | Osmotic distillation |
| p | : | Probability |
| pH | : | Hydrogen ion concentration |
| pp | : | Pages |
| Pvt. | : | Private |
| rpm | : | Revolution per minute |
| s | : | Second |
| S.Em | : | Standard error of mean |
| SPME | : | Solid phase microextraction |
| TSS | : | Total soluble solids |
| USA | : | United States of America |
| <i>viz.</i> | : | Namely |
| WAI | : | Water absorption index |
| wb | : | Wet basis |
| WSI | : | Water solubility index |
| w/w | : | Weight per weight |

LIST OF SYMBOLS

| | |
|---------------|---|
| ₹ | Rupees |
| % | Per cent |
| / | Per |
| > | Greater than |
| < | Smaller than |
| + | Plus |
| - | Minus |
| °C | Degree Celsius |
| °Brix | Degree Brix |
| ± | Plus or minus |
| θ | Theta |
| * | Interaction |
| ≤ | Less than or equal to |
| β | Beta |
| μ | Micro |
| x | Multiplication |
| μg | Microgram |
| μm | Micrometer |
| : | Colon |
| A | Area, m^2 |
| C | Specific heat, $\text{J/kg}^\circ\text{C}$ |
| h | Heat transfer coefficient, $\text{W/m}^2\ ^\circ\text{C}$ |
| I | Solar radiation, W/m^2 |
| k | Thermal conductivity, $\text{W/m}^2\ ^\circ\text{C}$ |
| L | Length of solar tunnel dryer, m |
| M | Mass, kg |
| T | Temperature, $^\circ\text{C}$ |
| T | Time, s, h |
| v | Velocity, m/s |
| ρ | Density, kg/m^3 |
| atm | atmosphere |

CHAPTER II

REVIEW OF LITERATURE

This chapter provides an overview of the existing literature concerning the physical properties, chemical composition, and drying rate of turmeric rhizomes. It specifically investigates how different pretreatment methods affect moisture content, color, curcumin content, total oil, total phenolic content, and drying rate. The main goal of this review is to establish a strong foundation for the current research project, entitled "Drying of turmeric (*curcuma longa*) in solar tunnel dryer". The objective of this study is to compile and evaluate previous studies on various turmeric processing techniques and their impact on quality parameters. Through a comprehensive analysis of the gathered literature, the study aims to acquire valuable insights for further investigation and analysis, thereby aligning with its research objectives.

2.1 Origin and scientific classification of turmeric

Turmeric, scientifically known as *Curcuma longa*, is a perennial herbaceous plant with rhizomes. It belongs to the ginger family, Zingiberaceae, and is native to tropical South Asia. It has been identified in a total of 133 different species worldwide. The name "turmeric" has its origins in the Latin term "terra merita," which means "meritorious earth." This name reflects the ground turmeric's vibrant and valuable color, resembling a mineral pigment.

Scientific classification (Anon., 2021d)

| | |
|-----------------|----------------------|
| Kingdom | <i>Plantae</i> |
| Division | <i>Magnoliophyta</i> |
| Class | <i>Liliopsida</i> |
| Subclass | <i>Zingiberidae</i> |
| Order | <i>Zingiberales</i> |
| Family | <i>Zingiberaceae</i> |
| Genus | <i>Curcuma</i> |
| Species | <i>C. longa</i> |
| Scientific Name | <i>Curcuma longa</i> |

In French, it is referred to as "terremerite," while in many other languages, it is commonly known as "yellow root." The name "*Curcuma*" has its roots in the Latin language and is recognized across different cultures (Benzie and Wachtel-Galor *et al.*, 2011).

2.2 Importance of turmeric

In India, several important varieties of turmeric were cultivated, each with its own unique characteristics and regions of cultivation. Some notable varieties include the 'Alleppey Finger' in Kerala, 'Salem turmeric' in Gujarat, 'Erode turmeric' in Tamil Nadu, 'Raja pore' and 'Sangli turmeric' in Maharashtra, and 'Nizamabad bulb' in Andhra Pradesh. Turmeric holds a significant position in both the food and pharmaceutical industries, being a key component in numerous food products and pharmaceutical formulations. In medicine, turmeric has diverse applications. It is used in cosmetic face creams and shows potential benefits in the prevention of Alzheimer's disease. In Indian Ayurvedic practices, turmeric is employed to address liver problems, high cholesterol, and digestive issues. It possesses properties that help inhibit blood clotting, strengthen the gall bladder, and treat skin diseases. Traditional Indian medicine extensively uses turmeric in the treatment of biliary disorders, anorexia, cough, diabetic wounds, hepatic disorders, rheumatism, and sinusitis (Ravindran *et al.*, 2007).

Turmeric has a composition that typically includes approximately 6.3% protein, 5.1% fat, 3.5% minerals, 69.4% carbohydrates, 13.1% moisture content, 3.5% essential oil, 2.5% to 6% curcumin, and 5.7% oleoresins (Kamble *et al.*, 2011). Curcumin content, oleoresin content, and essential oil content were key quality parameters for turmeric. In Tamil Nadu, the Erode local and *Salem* local varieties are particularly popular (Ravindran *et al.*, 2007).

After turmeric is harvested, it goes through a series of processing steps, including boiling, drying, and polishing. The polished rhizomes were then sorted into different categories based on their quality, such as fingers, bulbs, or broken pieces. These graded turmeric products are stored in cooperative marketing societies that have storage facilities provided by state or central warehousing corporations. This ensures secure storage for both farmers and traders. To prepare turmeric for export, it must undergo grading and pre-shipment inspection (Balakrishnan, 2007).

According to (Chanda and Ramachandra, 2019), turmeric is highly esteemed for its nutritional and medicinal properties. It contains a wide range of phytochemical compounds that contribute to its anti-disease capabilities. Traditional medicine, which utilizes medicinal plants like turmeric, is extensively practiced by approximately 80% of individuals in developed countries, as reported by the World Health Organization (WHO).

Turmeric powder has gained recognition as a traditional remedy for various gastrointestinal conditions, including biliary and hepatic disorders. It is also utilized in the treatment of diabetic wounds, inflammation, rheumatism, sinusitis, anorexia, coryza, and cough. Additionally, turmeric exhibits a wide range of health benefits, encompassing anticancer, anti-diabetic, anti-inflammatory, hypolipidemic, antioxidant, antibacterial, anti-fertility, anticoagulant, anti-venom, hepatoprotective, nephroprotective, and anti-HIV activities. These diverse medicinal properties of turmeric have garnered significant attention and contribute to its popularity as both a culinary spice and a traditional medicinal herb. Turmeric's remarkable properties make it a valuable resource in the fight against AIDS and various other health concerns.

2.3 Physicochemical properties of turmeric

2.3.1 Physical properties of fresh turmeric rhizomes

Dhineshkumar and Anandakumar (2016) studied the physical properties of turmeric (*Curcuma longa*) rhizome. To better understand its physical characteristics, they separated the sample (var. *Krishna, Salem*) into three categories (I: 30–40 mm, II: 40–50 mm, and III: 50–60 mm). The average range of geometric properties for grades I, II, and III are reported, including length of 30.18-48.54 mm, breadth of 9.72-10.62 mm, thickness of 5.12-6.38 mm, arithmetic mean diameter of 14.72-22.84 mm, geometric mean diameter of 12.72-14.64 mm, square mean diameter of 23.21-26.54 mm, equivalent diameter of 17.54-21.32 mm, sphericity of 0.24-0. The gravimetric characteristics, including the bulk density (264–348 kg/m³), true density (1340–1358 kg/m³), porosity (72.51–78.90%), and frictional characteristics, including the angle of friction,

Khambalkar *et al.* (2017) studied the physical properties of turmeric rhizomes. They took ten different varieties for the study viz., *PKV Waygaon, Survey Gadchiroli, Krishna, Salem, Bammi, SYN, Phuleswarupa, AKTR, Gondia, and Wardha*. Based on the experimentation conducted following conclusion could be drawn in Table 2.1.

Table 2.1 Physical properties of fresh turmeric rhizomes

| Sr. No. | Physical properties | Average value |
|---------|---------------------|---------------------------|
| 1 | Length | 58.11 mm |
| 2 | Breadth | 36.71 mm |
| 3 | Thickness | 30.17 mm |
| 4 | Weight | 34.87 g |
| 5 | Diameter | 50.57 mm |
| 6 | Sphericity | 0.71 mm |
| 7 | Bulk density | 529.66 kg/m ³ |
| 8 | True density | 1018.95 kg/m ³ |
| 9 | Porosity | 32 to 63% |
| 10 | Angle of repose | 18.06° |

2.3.2 Chemical composition and mineral composition of fresh turmeric rhizomes

Mane *et al.* (2018) reported the chemical composition and mineral composition of fresh turmeric rhizomes (var. *Salem*). Data about various chemical properties like moisture, fat, carbohydrates, protein, ash, curcumin, and crude fiber are depicted in Table 2.2 and various minerals such as Ca, P, K, Na, Mg, Fe, and Zn are depicted in Table 2.3.

Ahaotu and Lawal (2019) have determined proximate and minerals content of turmeric (*Curcuma longa* L.) leaves and rhizomes. It was observed that moisture (76.02%), carbohydrate (16.37%), ash (3.04%), crude fibre (1.95%), proteins (1.83%) and fat (0.80%) were present, respectively. Mineral content of the rhizomes gave the following higher to lower values; iron (0.57%) > potassium (0.42%) > magnesium (0.05%) > phosphorus (0.03%) > calcium (0.02%) > sodium (0.01%), respectively.

Table 2.2 Chemical composition of fresh turmeric rhizomes (*Selam*)

| Sr. No. | Chemical composition | Mean value* |
|---------|-------------------------|--------------|
| 1 | Moisture (%) | 84.25 ± 0.23 |
| 2 | Total fat (%) | 1.08 ± 0.13 |
| 3 | Total carbohydrates (%) | 9.10 ± 0.10 |
| 4 | Total protein (%) | 1.20 ± 0.07 |
| 5 | Ash (%) | 0.66 ± 0.01 |
| 6 | Crude fiber (%) | 0.72 ± 0.03 |
| 7 | Curcumin | 5.1 ± 0.17 |
| 8 | TSS (°Bx) | 7.8 ± 0.13 |
| 9 | pH | 7.8 ± 0.13 |
| 10 | Acidity | 0.70 ± 0.01 |

*Each value represents the average of three determinations

Table 2.3 Mineral composition of fresh turmeric rhizomes

| Sr. No. | Minerals | Average value (mg/100g)* |
|---------|------------|--------------------------|
| 1 | Calcium | 8.2 |
| 2 | Phosphorus | 0.12 |
| 3 | Sodium | 0.06 |
| 4 | Magnesium | 0.19 |
| 5 | Potassium | 1.70 |
| 6 | Iron | 2.4 |
| 7 | Zinc | 22.9 |

*Each value represents the average of three determinations

2.3.3 Physical properties of dried turmeric rhizomes

Shelake *et al.* (2018) undertook a study on the effect of different moisture content (6, 8, and 10% on a wet basis) on the physical properties and mechanical behavior of turmeric rhizome under laboratory conditions. It was noted that physical properties increased linearly with an increase in the moisture content of the rhizome. The moisture content showed a significant effect on the change in bulk density and

true density. However, properties like length, breadth, thickness, and porosity are not significantly affected by moisture content, which is depicted in Table 2.4

Parmar and Dabhi (2022) measured the physical properties of fresh turmeric rhizomes (Var. *Salem*). The sample of 50 turmeric rhizomes (*var. Salem*) was selected for analyzing their physical properties. The average weight of mother and finger rhizome were found 54.48 g and 28.15 g, respectively. The average values of their geometric properties viz. length (major dimension) (65.093 ± 9.11 mm), width (intermediate dimension) (40.58 ± 5.56 mm), thickness (minor dimension) (38.34 ± 3.24 mm), arithmetic mean diameter (51.36 ± 4.76 mm), square mean diameter (86.41 ± 7.80 mm), equivalent diameter (62.18 ± 5.63 mm), surface area (6341.39 ± 1106.62 mm²), unit volume (42162.05 ± 10765.23 mm³), shape factor (1.03 ± 0.07) were reported for mother rhizomes. The average size and sphericity for mother rhizomes were found 48.77 ± 4.35 mm and 0.652 ± 0.046 , respectively. The average values of their geometric properties viz. length (61.02 ± 19.51 mm), width (21.28 ± 3.43 mm), thickness (19.59 ± 3.52 mm), arithmetic mean diameter (33.95 ± 8.00 mm), square mean diameter (53.62 ± 11.08 mm), equivalent diameter (38.92 ± 8.20 mm), surface area (2422.52 ± 972.91 mm²), unit volume (8691.42 ± 4777.80 mm³), shape factor (1.050 ± 0.062) were reported for finger rhizomes. The average size and sphericity for finger rhizomes were found 29.17 ± 5.65 mm and 0.501 ± 0.090 , respectively.

Table 2.4 Physical properties of dried turmeric rhizomes

| Sr. No. | Physical properties | Mean Value (at 6 and 10% moisture content) |
|---------|---------------------|--|
| 1 | Length | 54.46 ± 8.45 to 55.79 ± 8.61 mm |
| 2 | Breadth | 12.48 ± 1.61 to 13.21 ± 1.13 mm |
| 3 | Thickness | 11.32 ± 1.41 to 11.65 ± 1.00 mm |
| 4 | Bulk density | 555 ± 0.84 to 563 ± 2.54 kg/m ³ |
| 5 | True density | 11.32 ± 1.41 to 11.65 ± 1.00 kg/m ³ |
| 6 | Porosity | 58.47 ± 0.04 to $58.57 \pm 0.02\%$ |

2.3.4 Chemical composition of turmeric powder

Ikpeama et al. (2014) conducted studies on the nutritional composition of turmeric and its antimicrobial properties. The result of the analysis is shown in Table 2.5.

Table 2.5 Chemical composition of dried turmeric rhizomes

| Sr. No. | Parameter | Composition (%) |
|---------|------------------|-----------------|
| 1 | Moisture content | 8.92 ± 0.02 |
| 2 | Ash content | 2.85 ± 0.02 |
| 3 | Crude fiber | 4.60 ± 0.01 |
| 4 | Crude protein | 9.40 ± 0.02 |
| 5 | Fat | 6.85 ± 0.00 |
| 6 | Carbohydrate | 67.38 ± 0.01 |

Imoru *et al.* (2018) measured the proximate, vitamins, minerals, and phytochemical compositions of turmeric rhizome powder. The results of the analyses indicated that the rhizome powder contains appreciable and high quantities of crude protein and carbohydrates of 10.07% and 66.76%, respectively. It also possesses significant levels of ash (2.76%), crude fiber (4.87%), ether extract (6.64%), and moisture content (8.91%). The total ash content revealed that the powder contains the following minerals in mg/g: 1.67 Ca, 0.92 Mg, 1.29 K, 1.07 P, 0.73 S and minute quantities of Cu, Se, and Fe.

2.4 Processing techniques

2.4.1 Blanching of turmeric rhizomes

Bambirra *et al.* (2002) studied that evaluate the influence of post-harvest processing conditions on the yield and quality of ground turmeric. Rhizomes were peeled, and cooked (autoclave or immersion) in water or alkaline media. Cooking by immersion resulted in better quality powder compared to autoclave. The use of alkaline media resulted in a product with lower curcuminoid content and higher intensity of yellow color.

Blasco *et al.* (2006) studied the blanching effect on turmeric drying. The drying kinetics of blanched and un-blanched turmeric rhizomes were investigated at various temperatures (60, 70, 80, 90, and 100°C). The study utilized one diffusion model and two empirical models (Weibull and Peleg) to characterize the mass transfer phenomenon during drying. It was observed that blanching prior to drying enhanced the drying rate across all tested temperatures. However, the influence of blanching on the drying rate diminished as the air-drying temperature increased. These findings

indicate that blanching can expedite the drying process, but its effectiveness is dependent on the specific drying conditions.

Suresh *et al.* (2007) 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 turmeric was 12.1-18.8 mg/g, with maximum loss in pressure cooking for 10 min.

Kamble and Soni (2009) conducted a study to improve the traditional turmeric boiling pot and reduce the losses in quality, time, and fuel in turmeric processing. The use of an improved boiling pot for turmeric resulted in higher retention of essential oils and curcumin compared to the traditional boiling pot. Specifically, the improved pot retained 3.33% essential oils and 2.30% curcumin, whereas the traditional pot retained 2.93% essential oils and 2.57% curcumin. Additionally, it was observed that boiling turmeric rhizomes for 35 minutes in the improved pot resulted in more uniform color compared to rhizomes boiled for 25 and 45 minutes. These findings highlight the beneficial effects of the improved boiling pot in preserving essential oils, curcumin, and color during the boiling process of turmeric.

Shinde *et al.* (2011) optimized the process of turmeric heat treatment by design and fabrication of a blancher at the College of Agricultural Engineering and Technology, Parbhani. In their research, the authors investigated the processing of turmeric using both traditional and steam blanching methods. They discovered that the steam cooking method resulted in a reduced fuel requirement compared to the traditional method. Furthermore, steam cooking led to a color loss in curcumin ranging from approximately 1.5% to 2.5%, while boiling caused a slightly higher color loss of around 1.6% to 3.5%. Based on these findings, the researchers concluded that steam treatment is a favorable option for both farmers and the turmeric processing industry.

Lokhande *et al.* (2013) studied the effect of curing and drying methods on the recovery of curcumin content and essential oil content in different turmeric cultivars. Based on the physicochemical analysis, the Krishna cultivars were determined to be the best among the three cultivars. However, the *Salem* and *Tekurpeta* cultivars exhibited higher values for color. When it comes to the curing process, the fingers

treated with the improved method showed a faster rate of moisture loss compared to both uncured fingers and those cured using traditional methods

Patil and Chhapkhane (2013) studied large-scale turmeric boiling by the use of conventional plants with multiple cookers and boiler assemblies placed on a trolley. The plant was equipped with a furnace, condensate extraction mechanism, packed pressure vessels, and a mobile plant. The turmeric rhizomes were placed in a cooker where boiling takes place, with steam being supplied from the boiler to the pressure cooker to boil the turmeric. Traditional plants usually lack pressure control during boiling, leading to inefficient processes. The current processing plant operates at a low efficiency of 13.19%, primarily due to significant losses occurring in various parts of the plant. Minimizing these losses at a reasonable cost is challenging. Therefore, the project aims to achieve the following objectives: reduce cooking time, decrease fuel consumption and heat losses, minimize labor effort and cost, and implement condensate recycling.

Anantkawlas, (2014) studied the treatments during the processing of cleaned rhizomes submerged in hot water in tins and boiled uniformly. After boiling, the cured rhizomes were poured into a bamboo basket to allow water drainage, and then they were dried in yards. This particular process imparts an appealing color and distinctive aroma to the turmeric. Boiling serves multiple purposes: it halts the growth of fresh rhizomes, eliminates any undesirable odor, reduces drying time, ensures uniform color distribution, and enhances the overall quality of the product through the gelatinization of starch present in the rhizomes.

Gagare *et al.* (2015) conducted a study at the College of Technology and Engineering, Udaipur, to optimize the curing and microwave drying process of turmeric (*Curcuma longa L.*) rhizomes. The researchers performed trials with different parameters, including curing by boiling the rhizomes in a 0.1% sodium carbonate solution for durations of 15, 30, and 45 minutes, and microwave drying at power levels of 1, 1.5, and 2 kW. Based on their observations, the quality of the cured turmeric samples was assessed in terms of color uniformity and appearance. It was found that the turmeric samples cured for 30 minutes exhibited the best quality, with a color uniformity score of 7.19 and an appearance score of 7.21. The researchers concluded that the optimal boiling time for curing the turmeric rhizomes and the ideal

power level for microwave drying were determined to be 30 minutes and 1.5 kW, respectively, to achieve the highest quality products. Overall, the study provided valuable insights into the optimization of the curing and microwave drying processes for turmeric rhizomes, enabling the production of turmeric with improved color uniformity and appearance.

Patil *et al.* (2015) compared the processing of turmeric by blanching to the conventional method of boiling the rhizomes at the College of Agricultural Engineering and Technology, Dapoli. During the study, the turmeric rhizomes were blanched and boiled for varying durations of 25, 30, and 35 minutes, after which they were dried. The researchers noted that the average dimensions of fresh turmeric rhizomes were 71.29 mm in length, 25.19 mm in width, and 24.08 mm in thickness. In comparison, the blanched turmeric rhizomes had slightly smaller dimensions, with average values of 69.72 mm in length, 24.42 mm in width, and 22.99 mm in thickness. The average weight, volume, and true density of fresh turmeric rhizomes were reported as 26.86 g, 26.15 cm³, and 1.026 g/cm³, respectively. On the other hand, the blanched turmeric rhizomes exhibited average values of 25.62 g, 24.23 cm³, and 1.07 g/cm³, respectively. Furthermore, the study revealed the curcumin content retained in the turmeric rhizomes after blanching and boiling for different durations. The results showed that the rhizomes blanched and boiled for 25, 30, and 35 minutes retained curcumin contents of approximately 4.27%, 4.09%, 4.01%, and 4.21%, 3.91%, 2.29%, respectively.

Sahu (2015) studied different turmeric processing methods to standardize the process treatment at Indira Gandhi Krishi Vishwavidyalaya, Raipur. The research focused on the effects of drying air temperature, sodium bicarbonate percentages, boiling periods, and slice thickness on the drying time of turmeric. The findings revealed that as the drying air temperature increased from 50 to 70°C, the drying time decreased significantly from 99 to 32 hours across all pretreatment samples with varying sodium bicarbonate percentages and boiling periods of 15, 30, and 45 minutes. In the case of non-boiled sliced samples, the drying time was further shortened by reducing the slice thickness from 3 to 1 cm. Similarly, samples that underwent vacuum treatment also exhibited reduced drying times with an increase in drying air temperature. Furthermore, the study observed that as the drying air

temperature increased, the moisture diffusivity of the turmeric samples also increased. It demonstrated that increasing drying air temperature and reducing slice thickness can effectively reduce the drying time. The findings contribute to the standardization of turmeric processing methods, which can enhance efficiency and optimize the quality of dried turmeric products.

Ettannil and Zachariah (2016) studied the processing of turmeric (*Curcuma longa* L.) by different curing methods and its effect on quality at the Indian Institute of Spices Research, Kerala. The study focused on the curing of Prathibha variety turmeric rhizomes using eight different methods. Slicing was found to significantly reduce the drying time to 9 days. Increasing the curing time from 30 to 60 minutes led to a notable reduction in all quality parameters. In the case of slicing, the curcumin, essential oil, and oleoresin content were measured at 5.71%, 3.07%, and 12.76%, respectively. These findings emphasize the impact of curing methods on turmeric quality, with slicing showing promising results in terms of drying time reduction. The specific values obtained provide valuable insights for assessing the quality of Prathibha variety turmeric.

Gan *et al.* (2016) studied the effect of drying and blanching on the retention of bioactive compounds in ginger and turmeric at the University of New South Wales, Sydney. The study revealed interesting findings regarding the retention of 6-gingerol during the drying process of ginger. It was determined that a short drying time at 60°C was optimal for retaining 6-gingerol. However, the researchers noted that variations in temperature conditions had a significant positive impact on 6-gingerol retention. On the other hand, blanching had a negative effect on the retention of 6-gingerol. The researchers conducted drying experiments under constant conditions at different temperatures (38°C, 48°C, 57°C, and 64°C) and relative humidity levels (20% and 40%). Among the non-blanching samples, drying at 57°C with a lower relative humidity yielded the highest amount of curcumin. Furthermore, the study concluded that blanching for 15 minutes resulted in the highest curcumin yield, while blanching for 5 minutes and 30 minutes did not have a significant effect on curcumin content. These findings provide valuable insights into the drying process of ginger and its impact on the retention of bioactive compounds. By optimizing drying conditions and minimizing blanching time.

Pradeep *et al.* (2016) studied the effect of blanching and drying methods on the quality characteristics of fresh turmeric rhizomes at the University of Mysore, Karnataka. To enhance the quality and color of turmeric powder, different drying methods were employed on turmeric rhizomes. These methods included sun drying under normal conditions (SDN) with temperatures ranging from 30 to 37°C and relative humidity of 30 to 35%, sun drying coupled with a black surface (SDB) with temperatures between 38 and 60°C and relative humidity of 28 to 31%, hot air drying (HA) at a temperature of 50±2°C and relative humidity of 58 to 63%, and low humidity air drying (LHA) at a constant temperature of 50°C and relative humidity of 28 to 30%. The study compared the drying efficiency of these methods and assessed the curcumin content in both blanched and unblanched turmeric slice samples. It was found that the average curcumin content for blanched samples was 4.1%, while unblanched samples had a slightly higher curcumin content of 4.6%. Notably, the highest curcumin content of 4.1% was observed in unblanched turmeric slices that were dried using mechanical drying, followed by sun drying coupled with a black surface

Bhat and Hedge (2018) studied the effect of pre-drying treatments and drying methods on drying time, moisture content, and dry recovery of turmeric at the College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka. The investigation deals with five pre-drying treatments namely, slicing, peeling, steaming, blanching with polythene sheet, and boiling, and three drying methods namely, solar drying, microwave drying and open sun drying. It was reported that among pre-drying treatments, steaming recorded the lowest drying time with the lowest final moisture content, and blanching with polythene sheet recorded 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.

Jayashree and Zachariah (2018) studied the effect of different curing methods including boiling in water for different durations (40, 60, and 90 min) and steam cooking (30, 45, and 60 min), dipping the rhizomes in boiling water for 10 min on quality of Prathiba variety turmeric. They reported that an increase in the curing time

of turmeric rhizomes resulted in a significant reduction in curcumin, starch, essential oil, and oleoresin content.

Pisalkar *et al.* (2018) studied the convective drying process for turmeric rhizomes at Indira Gandhi Krishi Vishwavidyalaya, Raipur. The study conducted experiments using fresh turmeric rhizomes and subjected them to different pretreatment methods, including blanching, curing, and non-treated samples sliced into a specific thickness. The pretreated samples were then mechanically dried using drying air temperatures of 50, 60, and 70°C, with a constant air velocity of 1 m/s. The analysis of the samples revealed variations in curcumin content, oleoresin content, and water activity. The curcumin content ranged from 2.04% to 2.95%, the oleoresin content ranged from 3.39% to 4.85%, and the water activity ranged from 0.59 to 0.64 across all samples. Based on the results obtained from convective drying, it was concluded that increasing the drying air temperature resulted in a reduction in drying time. This suggests that higher drying air temperatures contributed to faster moisture removal from the turmeric rhizomes during the drying process.

Raza *et al.* (2018) studied the effect of different drying treatments on the concentration of curcumin in raw *Curcuma longa* L. at the Department of Process and Food Engineering, Faculty of Engineering, Malaysia. During the 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.

Hirko *et al.* (2020) studied the effect of Curing and Drying Methods on the Biochemical Quality of Turmeric (*Curcuma longa*) Rhizome Grown in South Western Ethiopia. A study was conducted to determine the effects of boiling time, rhizome form and drying methods on the biochemical quality characteristics of turmeric. Boiling of unsliced rhizomes for 15 minutes followed by tunnel drying yielded higher oleoresin, curcumin and essential oil content. Boiling for 60 minutes then slicing

paired with sun drying resulted in a reduction of oleoresin, curcumin, and essential oil content. Among the various boiling time, rhizome form and drying techniques were studied, unsliced rhizome boiled for 15 minutes followed by poly tunnel solar drying was found superior biochemical quality.

Nithya *et al.* (2020) analyzed the effect of slicing, boiling, and drying methods on the extraction of curcumin, oleoresin, and essential oil content of ground turmeric at Tamil Nadu Agricultural University, India. In this study, various parameters were explored to assess their impact on the quality of turmeric powder. The parameters included different slice thicknesses (2 mm and 3 mm) and boiling methods using varying pressure levels (0.25, 0.5, 0.75, and 1 kg/cm²). Additionally, the drying methods investigated were tray drying, microwave drying, and vacuum drying, with water-boiled and sun-dried whole rhizomes serving as control samples. The control samples, consisting of water-boiled and sun-dried whole rhizomes, exhibited average values of curcumin content, oleoresin content, and essential oil content at 3.31%, 6.37%, and 2.33%, respectively. Among the different drying methods, the highest curcumin content of 4.35% was observed in un-boiled vacuum-dried turmeric

Korese and Achaglinkame (2022) studied the effect of slice thickness, pre-treatment, and drying air temperature on nutritional, and functional properties of *Gardenia erubescence* fruit powder at the Faculty of Agriculture, University for Development Studies, Ghana. The study involved the slicing of fresh *Gardenia erubescence* fruit into two thicknesses, 3mm and 5mm, followed by different pretreatment methods (steam blanching, dipping in 2% ascorbic acid solution, and no treatment) and subsequent drying at varying air temperatures (40°C, 50°C, 60°C, and 70°C). The pre-drying treatments had a significant impact on various quality parameters. The 5mm thick samples exhibited higher fiber and carbohydrate content but lower protein and fat content compared to the 3mm thick samples. Based on the results, it was concluded that drying the 5mm thick samples at a temperature of 60°C helped preserve the proximate and mineral contents. These findings highlight the influence of slice thickness and drying conditions on the nutritional composition of *Gardenia erubescence* fruit.

2.4.2 Drying methods of turmeric rhizomes

Saraswat and Verma (1988) developed a low-cost solar convective air dryer consisting of a collector, grain box, and chimney. The drying in the solar dryer proceeded from both the top and the bottom into the middle layer. They suggested that the dryer be placed on a revolving platform to regulate the amount of sunlight falling on the collector of the dryer.

Mujumdar Antoney (1989) developed a solar convective air grain dryer that consisted of a solar collector platform mounted on wheels, a grain box, and a chimney. To convert shortwave solar radiation into heat, an asbestos sheet coated with blackboard paint was placed on the platform. Polythene sheets were used to cover the asbestos sheet on the top and sides, creating an enclosure that trapped warm air. An inlet was provided at the front for airflow. The collector had dimensions of 2.2 x 1.5 square meters and gradually sloped towards the bottom of the grain box, allowing the heated air to pass through the grains. During the drying process, it was observed that the temperature at the outlet of the drying chamber was lower than the inlet air temperature. The drop in moisture content of the grains was found to be higher when the initial moisture content was higher and lower when the moisture content was already at a lower level. As the moisture content of the crop decreased, the drying rate slowed down. In a single day of drying for eight hours, the moisture content was reduced from 26.43% to 17.82%.

Jacob (1993) designed fabricated and tested a collector and cabinet-type solar copra dryer. The experiment was designed to investigate the effects of ambient temperature, time (9 am to 4 pm), and ambient relative humidity on the drying process. Different sets of experiments were conducted over four consecutive days for each variable. Several parameters were measured and analyzed, including the inlet temperature for the drying chamber, temperatures of the first and second batches, outlet temperatures, relative humidity inside the drying chamber, and moisture content of the copra. It was observed that the inlet temperature increased with the rise in ambient temperature until 2 pm, after which it started to decrease for all the sets. The maximum inlet temperature recorded was 64 °C, which corresponded to an ambient temperature of 45 °C. On the other hand, the minimum temperature observed was 40 °C, corresponding to an ambient temperature of 35 °C. Temperature variations were also observed between different batches. The maximum temperatures for the first

batch were measured at 56.5 °C, 58.0 °C, and 57.0 °C, while for the second batch, they were 56.0 °C, 56.5 °C, and 57 °C, depending on the different sets. A decrease in outlet temperature of the drying chamber (55.0 °C, 55.0 °C, and 55.4 °C for various sets) was noted due to the additional moisture released from the copra during the drying process. The relative humidity inside the chamber was found to be lower (39.5% at 9 am and 19% at 4 pm) compared to the ambient relative humidity (41.5% at 9 am and 26.5% at 4 pm).

Joy *et al.* (2001) used a German-made solar dryer to dry red chilies. The dryer setup consisted of a plastic foil-covered flat plate solar air heater, a drying tunnel, and small axial flow fans. Both the solar air heater and the drying tunnel had a floor length of 17 meters, with 10 meters dedicated to the tunnel and 7 meters to the heater. The breadth of the entire setup was 2 meters. Transparent UV-stabilized PE plastic foil, 0.2 mm thick with a visible radiation transmissivity of 92%, was used to cover both the solar air heater and the tunnel. To dry the chili fruits, they were spread in a single layer on a clean perforated mat placed inside the drying tunnel of the solar tunnel dryer, keeping them approximately 2 cm above the surface. Remarkably, the optimum drying time for red chilies in the solar tunnel dryer was only two days, while the conventional method typically took 7-10 days. When the ambient air temperature ranged between 34.3-36 °C and the relative humidity was between 51.1-54.9%, the dryer's internal temperature varied between 47.9-58.5 °C, with relative humidity ranging from 40.2-48.3%. Notably, the solar tunnel-dried samples exhibited higher capsaicin content and color value compared to samples dried using conventional methods.

Laaksonen and Roos (2003) designed a 12-meter-long and 2-meter width solar tunnel and constructed it to analyze the performance of the solar tunnel dryer using multiple drying and collector areas instead of a continuous single collector area followed by a single continuous drying area. Each solar collector in the setup had an area of 3 × 2 meters, and an equal drying area followed thereafter. This arrangement resulted in three drying zones and three collector zones covering the entire base of the tunnel. The flow of drying air was directed from the collector regions (north side) to the drying regions (south side) of the half-circled tunnel, where the product was to be dried. By maintaining an air velocity of approximately 0.25 m/s, the drying

temperature inside the tunnel could be easily elevated by around 5-30°C above the ambient temperature. In a test conducted using 135.8 kg of freshly harvested dates with an initial moisture content of 40.0% (wet basis), the dates were successfully dried to a final moisture content of 18.8% (wet basis) within a day (12 hours). Comparatively, the natural open-air sun drying method typically required 5-7 days to reach the same moisture content level. The results demonstrated that the drying process in the solar tunnel dryer was faster and more efficient than natural sun drying. Within a single day, the moisture content of the dates could be reduced to a safe storage level. Furthermore, the solar tunnel dryer yielded improved quality in terms of color, brightness, flavor, taste, and overall food value of the dried dates.

Gunasekar *et al.* (2006) conducted a comparative study on the effect of solar drying and sun drying of the turmeric variety Erode. Through observation, it was noted that the primary biochemical constituents of cured turmeric showed an increase in curcumin content as a result of boiling and drying. However, the levels of volatile essential oil, oleoresin, and total protein progressively decreased as the moisture content of the turmeric rhizomes decreased during the drying process.

Jose and Joy (2009) studied the solar tunnel drying of turmeric (*Curcuma longa* L.) for quality improvement at Sacred Heart College, Kochi, India. Thirty stations were used to gather newly harvested turmeric rhizomes, and trials were carried out using a variety of drying techniques, including solar tunnel drying, conventional drying, and industrial drying. It was found that the quality of the turmeric was preserved after standard processing. It was determined that solar tunnel drying was a more efficient way than conventional open sun drying since it retained more curcumin, volatile oil, and oleoresin while drying more quickly.

Arun *et al.* (2014) designed and fabricated a natural convection solar tunnel greenhouse dryer for studying the drying characteristics of coconuts in the Pollachi region of Tamil Nadu. In March 2014, three experimental runs were conducted using a dryer to dry 5000 coconuts. The main performance parameters studied were the drying time and the quality of the dried product. A comparison was made between the dryer and the traditional drying method, which involved open sun drying. The coconuts used in the experiment had an initial moisture content of 53.84% (wb). In the solar tunnel greenhouse dryer, these coconuts were dried to a final moisture

content of 7.4% (wb) within a drying time of 56 hours. On the other hand, the open sun drying method took 147 hours to achieve the same final moisture content for the coconuts. Furthermore, the quality of the dried coconuts obtained from the solar tunnel greenhouse dryer was superior to that of the coconuts dried using the open sun drying method. The dried coconuts from the solar tunnel greenhouse dryer were found to be free from fungal and bacterial infections, indicating a higher level of hygiene and quality control in the drying process. This outcome highlights the potential of the dryer to produce superior quality coconuts compared to the traditional open sun drying method.

Borah *et al.* (2015) studied the performance of drying turmeric in a solar conduction dryer (SCD) at Assam Agricultural University, India. The drying air temperature ranged from 39-51°C for an ambient temperature of 25-28°C. The initial moisture content of the samples was 78.65% (wb), and within 12 hours of effective drying time, it decreased to 6.36% (wb) for solid samples and 5.50% (wb) for sliced samples. The drying curve showed that the sliced samples had a more uniform drying pattern compared to the whole samples. The effective moisture diffusivities were determined to be 1.852×10^{-10} m²/s for sliced samples and 1.456×10^{-10} m²/s for whole samples. Therefore, it was concluded that drying sliced rhizomes exhibited better drying kinetics and reduced drying time compared to drying them in their whole form.

Krishna *et al.* (2016) designed and fabricated a multi-pass and multi-rack solar tunnel dryer. The use of a solar dryer as a viable method for safely and affordably preserving food products has been proven in this work. The dryer may be made without sophisticated technology. The dryer was tested after installation, and the maintenance costs were small. Based on the results, the following conclusion may be made. 1) The absorber's top temperature was measured at 65°C. 2) Compared to grapes dried in the open sun, grapes dried in a drying chamber had a higher nutritional value. 3) The solar dryer had a higher drying rate than the open-air sun drying technique. 4) After conducting tests without moving the trays, it was discovered that the tray that came into touch with the hot air initially dried the fastest of all the trays.

Gagare *et al.* (2017) conducted an experimental trial on the convective drying of turmeric (*Curcuma longa* L.) rhizomes at College Technology and Engineering,

Udaipur. Samples of the turmeric rhizome underwent a 30-minute curing procedure in a 0.1% sodium carbonate solution. The findings showed that 60°C was found to be the ideal drying air temperature for convective drying of turmeric rhizomes, with a drying period of 29 hours.

Pethkar *et al.* (2017) reported the thin layer was not desirable, as the color of the dried product may be adversely affected. During the nighttime, the material should be heaped or covered. It took 10-15 days for the rhizome to become completely dry.

Joseph *et al.* (2020) evaluated different methods for drying turmeric and extraction of curcumin at the Chemical Engineering Department, College of Engineering, Mumbai. The drying process for turmeric rhizomes was conducted using two different methods: an air dryer with temperatures ranging from 60°C to 100°C, and a solar conduction dryer with temperatures ranging from 39°C to 51°C. It was observed that as the air dryer temperature increased from 60°C to 100°C, the drying time decreased significantly from 6.5 hours to 1.5 hours. From the results solar conduction drying proved to be a more energy-efficient method for drying turmeric rhizomes, it had a considerably longer drying time compared to air drying.

Gill *et al.* (2020) studied the Turmeric (*Curcuma longa*) drying in natural circulation solar dryer. Normally, turmeric is hydrothermally pretreated before drying. So, the two conventional hydrothermal pretreatments of turmeric, water boiling and steam boiling were investigated. The products were sliced manually into thickness of 5 mm. In the hydrothermal pretreatment of water boiling, turmeric was immersed in boiling water for the time till froth started forming on the surface and the rhizome became soft. In the hydrothermal pretreatment of steam boiling, turmeric was exposed to steam in an autoclave for the time till steam pressure was raised to the level of 15 psi (103,421.3 Pa) and there after the pressure was released. The curcumin content hovered $\approx 3.0\%$ for unsliced turmeric and $\approx 2.8\%$ for sliced turmeric. The lower value of sliced turmeric might be due to loss of curcumin during drying of sliced of turmeric. This may be due to the reason that hydro-boiling pretreatment and longer drying time of untreated turmeric effect the curcumin reduction equally. The volatile oil content of unsliced turmeric was more ($\approx 5.9\%$) as compared to sliced turmeric ($\approx 5.5\%$)

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the pretreatments of turmeric, drying of turmeric by different methods, post-harvest operations of dried turmeric, quality analysis of dried turmeric and economic feasibility of the turmeric drying method. Methodologies adopted for the determination of the physical and biochemical properties of fresh and dried turmeric, as well as the drying characteristics of sliced and whole turmeric, quality evaluation of powders prepared using various treatments etc. are discussed in this chapter. The details of machinery, instruments and materials used in the experiments are also described hereunder.

3.1 Location and Year of Experiments

The experimental work is carried out in different departments as per the following details. All the experiments were carried out during the months of February to May - 2023.

1. Civil Engineering Wing, Department of Renewable Energy Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh.
2. Department of Processing and Food Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh.
3. Food Testing Laboratory, Department of Biotechnology, College of Agriculture, Junagadh Agricultural University, Junagadh.

3.2 Procurement of raw material

Fresh turmeric rhizomes (var. *Salem*) were procured from Purusharth Organic Farm, Sultanpur village, Gondal taluka of Rajkot district.

3.3 Sample preparation

The fresh turmeric rhizomes were washed thoroughly in tap water to remove the adhering soil, hairs, and extraneous matter. The undesirable portions were removed manually and then the rhizomes were again washed and cleaned properly. These washed and cleaned fresh turmeric rhizomes were used for further study.



Plate 3.1 Washing of raw turmeric rhizomes



Plate 3.2 Cleaning and separation of mother and finger rhizomes

3.4 Determination of moisture content of fresh turmeric rhizomes

To accurately assess the physical properties of turmeric rhizomes, it was necessary to measure the moisture content, as moisture levels can vary significantly. The moisture content % (wb) of fresh turmeric rhizomes was determined using the hot air oven method, following the procedure outlined by AOAC (2012a). Firstly, a pre-weighed petri dish was used to hold approximately 5-10 g of the turmeric sample. The weights of the empty dish and the dish with the sample were recorded separately. These petri dishes, loaded with the samples, were then placed inside a hot air oven (Scientronic-SON/45) maintained at $105 \pm 2^\circ\text{C}$ until a constant weight was achieved (Plate 3.3). After reaching a constant weight, the samples were allowed to cool in a desiccator and subsequently weighed again. The difference between the initial and final

sample weights represented the weight of the water that was removed during the drying process.

The moisture content of the fresh turmeric rhizomes was determined using the following formula (3.1):

$$\text{Moisture content(\% w. b.)} = \frac{W_i - W_o}{W_i} \quad \dots (3.1)$$

Where,

W_i = Initial weight of sample, g

W_o = Final weight of sample, g



Plate 3.3 Hot air oven used for experiment work

3.5 Determination of physical properties of turmeric rhizomes

Various physical properties of turmeric rhizomes, viz., size, Sphericity, bulk density, true density and porosity were measured with the help of different instruments and as per standard methods.

3.5.1 Size

To determine the size of turmeric rhizomes, a random selection of 30 rhizomes was chosen. Using a digital Vernier caliper (Mitutoyo/CD-12"PSX), the major dimension (l), minor dimension (t), and intermediate dimension (b) of each rhizome were measured after calibrating the caliper to zero. To measure the dimensions, the lower jaws of the caliper were adjusted to lightly touch the surfaces of the rhizomes, and the reading on the LCD display was recorded. This was achieved by applying gentle

pressure with the thumb screw (Plate 3.4). Once the measurements were obtained, the size of each rhizome, indicated by the geometric mean diameter, was calculated using the formula (3.2) proposed by Mohsenin (1986). Finally, the average of all the observations was calculated to determine the average size of the turmeric rhizomes.

$$\text{Size (mm)} = (lbt)^{\frac{1}{3}} \quad \dots (3.2)$$

Where,

l = maximum perpendicular dimension, mm

b = intermediate perpendicular dimension, mm

t = minimum perpendicular dimension, mm

3.5.2 Sphericity

The sphericity of a turmeric rhizome was determined by using the major, minor, and intermediate dimensions with the help of a formula (3.3) given by Mohsenin (1986).

$$\text{Sphericity} = \frac{(lbt)^{\frac{1}{3}}}{l} \quad \dots (3.3)$$

Where,

l = maximum perpendicular dimension, mm

b = intermediate perpendicular dimension, mm

t = minimum perpendicular dimension, mm



Plate 3.4 Measurement of dimensions of turmeric rhizomes using Vernier caliper

3.5.3 Bulk density

To determine the bulk density of turmeric rhizomes, a pre-weighed graduated narrow flask was used. The rhizomes were filled into the flask up to a specific volume, ensuring that the top surface remained flat and aligned with the graduated mark (Plate 3.5). Then, the mass of the rhizomes was weighed to the nearest 0.001 g and recorded. Using the measured mass (M) and the volume up to which the rhizomes were filled (V), the bulk density of the rhizomes was determined using the formula (3.4) given by Mohsenin (1986). The average of five different observations was calculated.

$$\text{Bulk density} = \frac{M(g)}{V(\text{cm}^3)} \quad \dots (3.4)$$



Plate 3.5 Measurement of bulk density

3.5.4 True Density

The true density of turmeric rhizomes is determined by comparing the weight of an individual rhizome to its volume. This measurement is carried out using the liquid displacement technique with toluene (Plate 3.6). It is worth noting that turmeric rhizomes do not absorb toluene within the short duration required for the measurement. The density of toluene utilized in this process is 0.87 g/cm³. To calculate the true density, the following formula (3.5) given by Mohsenin (1986) is utilized.

$$\text{True Density} = \left[\frac{\text{Weight of sample } (W_1) \text{ (g)}}{\text{Volume of sample } (V) \text{ (cm}^3\text{)}} \right] \quad \dots (3.5)$$

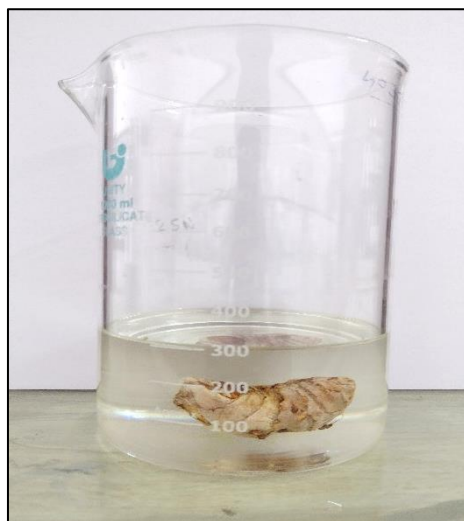


Plate 3.6 Measurement of true density

3.5.5 Porosity

Porosity was determined by using the values of bulk density and true density as per the equation (3.6) which is given by Mohsenin (1986).

$$\text{Porosity (\%)} = \left[\frac{\text{True density } \left(\frac{\text{g}}{\text{cm}^3} \right) - \text{Bulk density } \left(\frac{\text{g}}{\text{cm}^3} \right)}{\text{True density } \left(\frac{\text{g}}{\text{cm}^3} \right)} \right] \times 100 \quad \dots (3.6)$$

3.6 Experimental procedure

3.6.1 Cleaning of turmeric rhizomes

Harvested rhizomes were cleaned from mud and other extraneous matter adhering to them as mentioned in section 3.3.

3.6.2 Peeling of turmeric rhizomes

The peeling of a cleaned and washed turmeric rhizome was done by using a mechanical peeler (SS/415) (Plate 3.7). A machine designed to slowly and carefully

remove the outer layers of turmeric is put inside a peeler removes the peel or skin from turmeric.



Plate 3.7 Peeling of turmeric rhizomes was done by using a mechanical peeler

3.6.3 Slicing of turmeric rhizomes

Slicing was done by using a hand slicer (Plate 3.8). The thickness of turmeric rhizomes was adjusted by an adjustable knob. The thickness of the slice was measured by using a digital Vernier caliper (Mitutoyo).



Plate 3.8 Slicing of turmeric rhizomes

3.6.4 Blanching of turmeric rhizomes

The slices and whole turmeric underwent a blanching process using an autoclave at temperatures of 70°C, 80°C, and 90°C, under atmospheric pressure, for various durations: 15 minutes, 30 minutes, and 45 minutes. After completing the blanching treatment, the rhizomes were removed from the autoclave and left to cool at room temperature. The photograph of blanched rhizomes is given in (Plate 3.9).



Plate 3.9 Blanching of turmeric rhizomes

3.6.5 Drying of turmeric rhizomes

To reduce the moisture content of the blanched slices and whole turmeric rhizomes, a drying process is necessary to reach the desired safe moisture level. Two different drying methods, viz., solar tunnel drying, sun drying was used in the present investigation.

3.6.5.1 Solar tunnel drying

The present study was carried out to evaluate the drying characteristics of fresh turmeric rhizomes at different blanching temperatures, times and slice thicknesses. A solar tunnel dryer was employed for the drying process. Whole and sliced turmeric were blanched at three different temperatures (70°C, 80°C, and 90°C), times (15, 30 and 45 minutes) and thicknesses (4 mm, 5 mm and whole). In the drying procedure, plastic mesh nets were used to evenly distribute 700 grams of turmeric samples on flat SS trays material spread density of 214.3 kg/m³ was employed. Each tray contained three samples, and these trays were then placed on a tray stand. The weight loss of the samples was recorded at interval of 1 hour interval using an electronic weighing balance. The inside and outside (ambient) temperature of the solar tunnel

dryer was recorded with the help of data logger throughout the experiment. In addition to these, solar radiation intensity and relative humidity inside and outside (ambient) the tunnel was also recorded. The drying was stopped when the weight of the drying samples of different treatments at almost constant level.



Plate 3.10 Solar tunnel drying of turmeric

3.6.5.1.1 Components of solar tunnel dryer:

The experiments on drying of sliced and whole turmeric (*Curcuma longa*), were conducted using a solar tunnel dryer developed at the Department of Renewable Energy Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. Detailed information regarding the different components of the solar tunnel dryer, along with their specifications, materials and constructional details are mentioned in Table 3.1.



Plate 3.11 Solar Tunnel Dryer used for experiment work

Table 3.1 Details of solar tunnel dryer

| Sr. No. | Specifications | Details |
|---------|--------------------------------------|--|
| 1 | Type of dryer | Natural convection-type solar tunnel dryer |
| 2 | Dryer dimension | 10 m x 5 m x 2.5 m |
| 3 | Shape | Hemi-cylindrical |
| 4 | Size of tray | 0.70 m X 0.70 m x 0.05 m |
| 5 | Number of trays | 64 (16 trays per stand arranged in two-tier) |
| 6 | Total number of trays stands | 4 |
| 7 | A total volume of 64 trays | 1.57m ³ |
| 8 | Number of air vents | 5 |
| 9 | Air vent dimension | 16.5 cm x 16.5 cm |
| 10 | Number of turbo ventilators | 2 |
| 11 | Number of exhaust fan | 2 |
| 12 | Solar tunnel dryer covering material | UV stabilized 200 μ polyethylene sheet |

1) Details of Solar Tunnel Dryer used for experimental work:

RCC platform:

- The main function of the RCC platform is to provide support to the structure of entire solar tunnel dryer.
- The main purpose of the RCC platform is to strengthen, secure and insulate the base of the solar tunnel dryer.
- 10 pieces of galvanized square pipes of size 50 mm x 50 mm x 2 mm 15 inches long are fixed in the RCC plaster at a distance of 2 meters on both sides above the platform at a distance of 40 cm from each side of the outer side of the platform, i.e., RCC platform has



been drilled to a depth of 12 inches, i.e., 0, 2, 4, 6, 8 and 10 m intervals to hold 50 mm x 50 mm x 2 mm 15 inches long.

- Six arcs of GI square pipes (40 mm x 40 mm x 1.2 mm) were reinforced to this hole to hold both the ends of arcs.
- All the sides of STD structures were supported with square GI pipes of 35 mm x 35 mm x 2 mm throughout the circumference of arcs on both the side. Fitting the arches and welding them with nut-bolts.
- Additional strength to the solar tunnel dryer structure is provided by welding side supports of 35 mm x 35 mm x 2 mm square pipes to six arches of length 8.5 m at equal

Solar Tunnel Dryer Structure:

- On the north side of solar tunnel dryer structure G.I. 3.75 ft wide and 10 m long north wall made GI of sheet (22 gauge).
- On the north side of solar tunnel dryer structure G.I. 3.75 ft wide and 10 m long north wall made GI of sheet (22 gauge).
- North wall is welded with north side supports of STD.
- Front side of north wall inside the STD was painted black to minimize the heat loss.
- On the north side of solar tunnel dryer structure G.I. 3.75 ft wide and 10 m long north wall made GI of sheet (22 gauge).
- North wall is welded with north side supports of STD.
- Front side of north wall inside the STD was painted black to minimize the heat loss.
- A 40 mm thick polystyrene sheet of length 10 meters long and 3.5 feet polystyrene sheet was placed at the rear of the north wall to insulate the northern wall.



- The main purpose of north wall is to absorb reflected solar radiation and heat loss on north side was minimized.

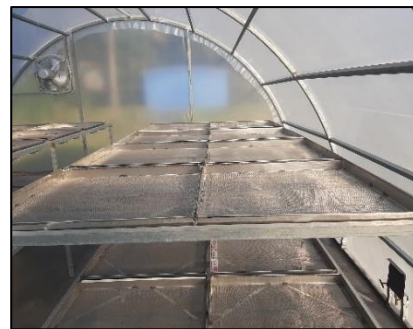
Air vents:

- It is used to introduce ambient air inside 16.5 cm X 16.5 cm square air vents (air windows) for introducing fresh atmospheric air
- 5 air vents (size 16.5cm X 16.5cm) are located above the bottom floor at interval of 160 cm towards the south side of solar tunnel dryer structure.
- These air vents are kept open when STD operated on natural air convection mode. However, air vents are kept closed with sliding door or attached with outlet pipe of solar flat plate collectors when STD operated on forced air convection mode



Drying tray with stand

- Two self-powered turbo ventilators (21" throat and 28" aluminum mounting diameter) were placed on the roof of the solar tunnel dryer to exhaust the hot air inside. Air circulates the air entering the solar tunnel dryer through vents (air windows).
- Turbo ventilators kept open when solar tunnel dryer operated on natural air convection mode. However, kept closed by sliding bottom shutter when the solar tunnel dryer operated on forced air convection mode.



Drying Tray

- The size of drying tray was kept 700 mm x 700 mm x 50 mm with net volume of 0.0245 m³. Total number of 64 trays were fabricated to accommodate 500 kg fresh red chillies.
- The side support of the drying tray in the form of angle frame of sized 50 mm x 20 mm x 0.8 mm was fabricated from SS 202 material, whereas wire mesh (700 mm x 700 mm) was made of SS 304 grade with 10 to 11 perforations per inch.
- The wire mesh was fixed in the formed angle frame with spot welding.
- Additional diagonal strip of SS 202 material was also spot welded at the four corners of drying tray to give more strength.
- Total volume (capacity) of 64 trays is 1.57 m³, in which approximately 500 kg of red chillies, 550 kg of ginger and 575 kg of turmeric could be dried per batch.
- drying trays, i.e., each stand accommodates 16 numbers of drying trays (700 mm x 700 mm x 50 mm) in two tier (8 no. in upper tier and 8 no. in lower tier).
- The drying tray stand main frames were made of 35mm X 35mm X 2mm square GI pipes, whereas side of the main frame was supported with by 25mm X 25mm X 1.2mm square GI pipes.



3.6.5.2 Sun drying

The experiment on sun drying of turmeric was carried out in the Department of Renewable Energy Engineering, CAET, JAU, Junagadh as well as at the village Sultanpur of Mangrol Taluka.

The present study was carried out to evaluate the drying characteristics of fresh turmeric rhizomes at different blanching temperatures, times and slice thicknesses. Traditional, sun drying was used as a drying method. Turmeric was blanched at three different temperatures (70°C, 80°C, and 90°C), times (15, 30 and 45 minutes) and thicknesses (4 mm, 5 mm and whole). In the sun-drying study, a total of 700 grams of

turmeric samples were evenly spread over the double-layer plastic mesh nets and all sample were placed on the cleaned and leveled ground surface, where plenty of sun light is available throughout the day. The drying process was conducted during the daytime, i.e., 8 am to 6 pm. During the night time, the sample were gathered and covered as per the its treatment order in the field to protect samples throughout the overnight. The weight loss of the samples was recorded at interval of 1 hour using an electronic weighing balance. The drying was stopped when the weight of the drying samples attained a almost constant level, i.e., about 9 to 10% on a % (wb).

However, sun drying of whole turmeric rhizomes (1000 kg) without peeling was carried out as per the method followed by the local farmers at village Sultanpur of Mangrol Taluka. First, harvested turmeric rhizomes were cleaned with clean water to remove external impurities, viz., soil, hair, extraneous materials, etc. Then after, these cleaned rhizomes are immersed in a big vessel filled with the about 100 lit of water. Quantity of turmeric rhizomes was kept about 1.75 to 1.85 times (175 to 180 kg) more than the weight of water. After that, this vessel is heated till up to the boiling point of water for about 1 to 1.5 hour. When pleasant fragrance of turmeric starts the boiling process is stopped. Then after, water is drained and boiled rhizomes separated in kept under cooled air.

Blanched whole turmeric rhizomes were uniformly spread about 2 to 3 cm bed thickness over plastic mesh or over a cotton cloth on the earth surface. Whole turmeric rhizomes were exposed to direct sun light during day time, however, after 18.00 hour, covered with plastic cover to protect it from dew, fog, rain, etc. during overnight.



Plate 3.12 Sun Drying

Sun drying is continued till the rhizomes are dried thoroughly on the field. These dried rhizomes are polished by rubbing the rhizomes over rough Kacha floor with help of jute bag. Then after, grinding, milling, sieving and packaging operations are carried out to dried turmeric powder.

3.7 Experimental plan

The complete experiment involved the utilization of two distinct drying techniques. In the initial approach, the rhizomes were subjected to solar tunnel drying, while in the second method, the rhizomes underwent sun drying.

3.7.1 Experimental design and analysis of turmeric rhizomes by solar tunnel drying and sun drying

The experimental design for the study of turmeric rhizome drying involved three factors: blanching time, blanching temperature, drying method, and rhizome form. Blanching time was varied at three levels: 15, 30, and 45 minutes. The blanching temperature was set at three levels: 70 °C, 80 °C, and 90 °C. The drying method included two types: solar tunnel drying and sun drying. The rhizome forms used were sliced (4mm and 5mm) and unsliced. This resulted in a $3 \times 3 \times 3$ factorial design, resulting in a total of 54 experimental units. Each experimental unit was replicated twice, bringing the total number of experimental units to 108. The experimental layout followed a Factorial Completely Randomized Design (FCRD), where the treatments were randomly assigned to the experimental units. This factorial design allowed for the investigation of the individual and interactive effects of blanching time, blanching temperature, drying method, and rhizome thickness on the drying process and the resulting quality of the turmeric rhizomes.

3.7.2 Details of treatments

The details of treatments in terms of independent and dependent parameters are given below.

Independent variables

1. First factor : Blanching temperature (B) with three levels
B₁ : 70 °C
B₂ : 80 °C
B₃ : 90 °C
2. Second factor : Blanching time (M) with three levels
M₁ : 15 min
M₂ : 30 min
M₃ : 45 min
3. Third factor : Slice thickness (S) with three levels
S₁ : 4 mm
S₂ : 5 mm
S₃ : whole rhizomes
4. Fourth factor : Drying methods (D) with two levels
D₁ : solar tunnel drying
D₂ : sun drying
5. Treatment combinations : 54
6. No. of replications : 2
7. Total treatments : 108

Dependent variables

8. Solar tunnel drying : Moisture content, drying rate, moisture ratio (MR)
9. Sun drying : Moisture content, drying rate, moisture ratio (MR)

Table 3.2(a) Treatment combinations details for drying turmeric using solar tunnel dryer

| Sr. No. | Treatment Detail | Combination |
|----------------|--|---|
| 1 | T ₁ (B ₁ M ₁ S ₁ D ₁) | 70°C Temp. + 15 min. Blanching + 4 mm size + STD |
| 2 | T ₂ (B ₁ M ₁ S ₂ D ₁) | 70°C Temp. + 15 min. Blanching + 5 mm size + STD |
| 3 | T ₃ (B ₁ M ₁ S ₃ D ₁) | 70°C Temp. + 15 min. Blanching + whole size + STD |
| 4 | T ₄ (B ₁ M ₂ S ₁ D ₁) | 70°C Temp. + 30 min. Blanching + 4 mm size + STD |
| 5 | T ₅ (B ₁ M ₂ S ₂ D ₁) | 70°C Temp. + 30 min. Blanching + 5 mm size + STD |
| 6 | T ₆ (B ₁ M ₂ S ₃ D ₁) | 70°C Temp. + 30 min. Blanching + whole size + STD |
| 7 | T ₇ (B ₁ M ₃ S ₁ D ₁) | 70°C Temp. + 45 min. Blanching + 4 mm size + STD |
| 8 | T ₈ (B ₁ M ₃ S ₂ D ₁) | 70°C Temp. + 45 min. Blanching + 5 mm size + STD |
| 9 | T ₉ (B ₁ M ₃ S ₃ D ₁) | 70°C Temp. + 45 min. Blanching + whole size + STD |
| 10 | T ₁₀ (B ₂ M ₁ S ₁ D ₁) | 80°C Temp. + 15 min. Blanching + 4mm size + STD |
| 11 | T ₁₁ (B ₂ M ₁ S ₂ D ₁) | 80°C Temp. + 15 min. Blanching + 5mm size + STD |
| 12 | T ₁₂ (B ₂ M ₁ S ₃ D ₁) | 80°C Temp. + 15 min. Blanching + whole size + STD |
| 13 | T ₁₃ (B ₂ M ₂ S ₁ D ₁) | 80°C Temp. + 30 min. Blanching + 4mm size + STD |
| 14 | T ₁₄ (B ₂ M ₂ S ₂ D ₁) | 80°C Temp. + 30 min. Blanching + 5mm size + STD |
| 15 | T ₁₅ (B ₂ M ₂ S ₃ D ₁) | 80°C Temp. + 30 min. Blanching + whole size + STD |
| 16 | T ₁₆ (B ₂ M ₃ S ₁ D ₁) | 80°C Temp. + 45 min. Blanching + 4mm size + STD |
| 17 | T ₁₇ (B ₂ M ₃ S ₂ D ₁) | 80°C Temp. + 45 min. Blanching + 5mm size + STD |
| 18 | T ₁₈ (B ₂ M ₃ S ₃ D ₁) | 80°C Temp. + 45 min. Blanching + whole size + STD |
| 19 | T ₁₉ (B ₃ M ₁ S ₁ D ₁) | 90°C Temp. + 15 min. Blanching + 4mm size + STD |
| 20 | T ₂₀ (B ₃ M ₁ S ₂ D ₁) | 90°C Temp. + 15 min. Blanching + 5mm size + STD |
| 21 | T ₂₁ (B ₃ M ₁ S ₃ D ₁) | 90°C Temp. + 15 min. Blanching + whole size + STD |
| 22 | T ₂₂ (B ₃ M ₂ S ₁ D ₁) | 90°C Temp. + 30 min. Blanching + 4mm size + STD |
| 23 | T ₂₃ (B ₃ M ₂ S ₂ D ₁) | 90°C Temp. + 30 min. Blanching + 5mm size + STD |
| 24 | T ₂₄ (B ₃ M ₂ S ₃ D ₁) | 90°C Temp. + 30 min. Blanching + whole size + STD |
| 25 | T ₂₅ (B ₃ M ₃ S ₁ D ₁) | 90°C Temp. + 45 min. Blanching + 4mm size + STD |
| 26 | T ₂₆ (B ₃ M ₃ S ₂ D ₁) | 90°C Temp. + 45 min. Blanching + 5mm size + STD |
| 27 | T ₂₇ (B ₃ M ₃ S ₃ D ₁) | 90°C Temp. + 45 min. Blanching + whole size + STD |

Key Words: B = Blanching temp, M = Blanching time, S = turmeric size,

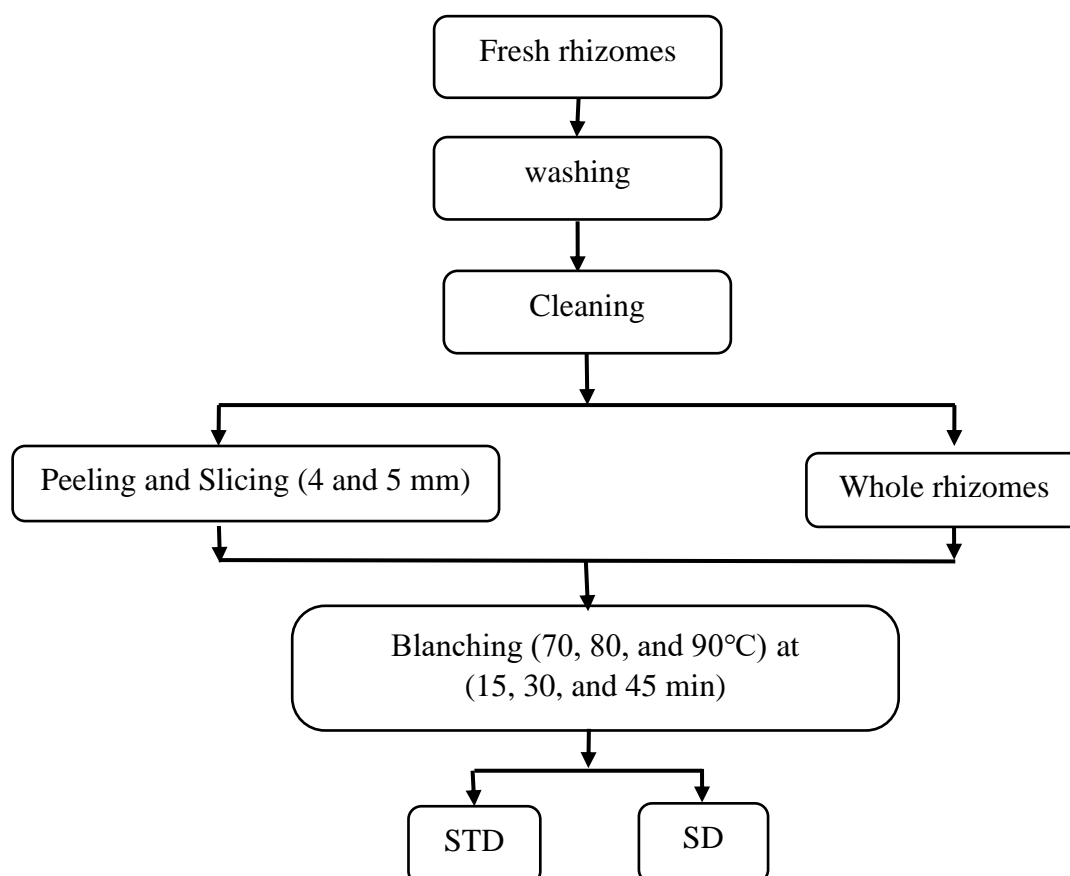
D₁ = Solar Tunnel Dryer, D₂ = Sun Drying

Table 3.2(b) Treatment combinations details for drying turmeric using sun drying

| Sr. No. | Treatment Details | Combinations |
|----------------|--|--|
| 1 | T ₁ (B ₁ M ₁ S ₁ D ₂) | 70°C Temp. + 15 min. Blanching + 4 mm size + SD |
| 2 | T ₂ (B ₁ M ₁ S ₂ D ₂) | 70°C Temp. + 15 min. Blanching + 5 mm size + SD |
| 3 | T ₃ (B ₁ M ₁ S ₃ D ₂) | 70°C Temp. + 15 min. Blanching + whole size + SD |
| 4 | T ₄ (B ₁ M ₂ S ₁ D ₂) | 70°C Temp. + 30 min. Blanching + 4 mm size + SD |
| 5 | T ₅ (B ₁ M ₂ S ₂ D ₂) | 70°C Temp. + 30 min. Blanching + 5 mm size + SD |
| 6 | T ₆ (B ₁ M ₂ S ₃ D ₂) | 70°C Temp. + 30 min. Blanching + whole size + SD |
| 7 | T ₇ (B ₁ M ₃ S ₁ D ₂) | 70°C Temp. + 45 min. Blanching + 4 mm size + SD |
| 8 | T ₈ (B ₁ M ₃ S ₂ D ₂) | 70°C Temp. + 45 min. Blanching + 5 mm size + SD |
| 9 | T ₉ (B ₁ M ₃ S ₃ D ₂) | 70°C Temp. + 45 min. Blanching + whole size + SD |
| 10 | T ₁₀ (B ₂ M ₁ S ₁ D ₂) | 80°C Temp. + 15 min. Blanching + 4mm size + SD |
| 11 | T ₁₁ (B ₂ M ₁ S ₂ D ₂) | 80°C Temp. + 15 min. Blanching + 5mm size + SD |
| 12 | T ₁₂ (B ₂ M ₁ S ₃ D ₂) | 80°C Temp. + 15 min. Blanching + whole size + SD |
| 13 | T ₁₃ (B ₂ M ₂ S ₁ D ₂) | 80°C Temp. + 30 min. Blanching + 4mm size + SD |
| 14 | T ₁₄ (B ₂ M ₂ S ₂ D ₂) | 80°C Temp. + 30 min. Blanching + 5mm size + SD |
| 15 | T ₁₅ (B ₂ M ₂ S ₃ D ₂) | 80°C Temp. + 30 min. Blanching + whole size + SD |
| 16 | T ₁₆ (B ₂ M ₃ S ₁ D ₂) | 80°C Temp. + 45 min. Blanching + 4mm size + SD |
| 17 | T ₁₇ (B ₂ M ₃ S ₂ D ₂) | 80°C Temp. + 45 min. Blanching + 5mm size + SD |
| 18 | T ₁₈ (B ₂ M ₃ S ₃ D ₂) | 80°C Temp. + 45 min. Blanching + whole size + SD |
| 19 | T ₁₉ (B ₃ M ₁ S ₁ D ₂) | 90°C Temp. + 15 min. Blanching + 4mm size + SD |
| 20 | T ₂₀ (B ₃ M ₁ S ₂ D ₂) | 90°C Temp. + 15 min. Blanching + 5mm size + SD |
| 21 | T ₂₁ (B ₃ M ₁ S ₃ D ₂) | 90°C Temp. + 15 min. Blanching + whole size + SD |
| 22 | T ₂₂ (B ₃ M ₂ S ₁ D ₂) | 90°C Temp. + 30 min. Blanching + 4mm size + SD |
| 23 | T ₂₃ (B ₃ M ₂ S ₂ D ₂) | 90°C Temp. + 30 min. Blanching + 5mm size + SD |
| 24 | T ₂₄ (B ₃ M ₂ S ₃ D ₂) | 90°C Temp. + 30 min. Blanching + whole size + SD |
| 25 | T ₂₅ (B ₃ M ₃ S ₁ D ₂) | 90°C Temp. + 45 min. Blanching + 4mm size + SD |
| 26 | T ₂₆ (B ₃ M ₃ S ₂ D ₂) | 90°C Temp. + 45 min. Blanching + 5mm size + SD |
| 27 | T ₂₇ (B ₃ M ₃ S ₃ D ₂) | 90°C Temp. + 45 min. Blanching + whole size + SD |

3.7.3 Drying of blanched turmeric (sliced and whole) by STD and SD

The details of the different steps followed in the drying of blanched sliced and whole turmeric are elaborated as under in the process flow chart (Fig. 3.1)



Note: STD = Solar Tunnel Drying, SD = Sun Drying,

Fig. 3.1 Process flow chart of blanched turmeric using different drying methods

3.8 Drying characteristics

Different drying characteristics of turmeric rhizomes viz. moisture content, drying rate, moisture ratio and drying time were calculated using the methods suggested by Chakraverty (1994).

3.8.1 Moisture content

The moisture content (% wb) of dried turmeric rhizomes was determined by the AOAC (2012b) as described in section 3.4. The moisture content (% wb) was converted into moisture content (% db) using the following relationship.

$$\text{Moisture content (\% d. b.)} = \frac{\text{moisture content (decimal w.b.)}}{1 - \text{moisture content (decimal w.b.)}} \times 100 \quad \dots (3.7)$$

3.8.2 Drying rate

The moisture content data recorded during experiments were analyzed to determine the moisture lost by turmeric rhizomes in a particular time interval. The drying rate of the sample was then calculated by the following equation (3.8).

Drying rate per given time interval (g water/min/100 g dry matter)

$$= \frac{\text{Weight of water removed during given time interval, g}}{\text{Drying time interval, min} \times \left(\frac{\text{Dry matter, g}}{100}\right)} \times 100 \quad \dots (3.8)$$

3.8.3 Moisture ratio

The moisture ratio for the drying process of dried turmeric rhizomes was estimated using the equation described below (3.9).

$$\text{Moisture ratio} = \frac{M - M_e}{M_o - M_e} \quad \dots (3.9)$$

3.8.4 Drying time

Moisture lost by the turmeric rhizomes in a particular time interval was noted up to the weight of the drying rhizomes in consecutive terms remains constant.

3.9 Determination of biochemical parameters of dried turmeric

Biochemical parameters of dried turmeric obtained through different treatments were determined by using standard methods. All the samples with two replications were analyzed at a time for the determination of a particular parameter.

3.9.1 Total carbohydrate

The phenol sulphuric acid technique was used to calculate total carbohydrates (Dubois *et al.*, 1956). In a boiling water bath (Nova, Digital constant temperature) for three hours with 10 ml of 2.5 N HCl, 0.1 g of the sample was hydrolyzed before being cooled to room temperature. After that, centrifugation was used. After that, a prepared HCl solution was used to dilute the sample extract 10 times. Following this, 0.1 ml of the sample aliquot were pipetted into two different test tubes. Then, each tube was filled

to a final volume of 1 ml of solution. The blank solution was 1 ml of distilled water in a test tube. Each tube was then filled with 1 ml of 5% phenol and 5 ml of 96% sulphuric acid. After thoroughly shaking the tubes, the color was determined at 490 nm using a UV-Visible spectrophotometer (Thermo Scientific, GENESYS 50). The construction of the standard glucose graph was then used to determine the amount of carbs. The following formula was used.

Total carbohydrate (%) =

$$\frac{\text{Graph factor } (\mu\text{g}) \times \text{Optical density} \times \text{Dilution factor} \times \text{Total vol. (ml)} \times 10^{-6}}{\text{Sample aliquot (ml)} \times \text{Weight of sample (g)}} \times 100 \quad \dots (3.10)$$



Plate 3.13 Determination of total carbohydrates

3.9.2 True protein content

The quantification of true protein content was determined using the Folin-Lowry assay following the procedure described by (Lowry *et al.* in 1951). Approximately 0.1 g of the sample, was dissolved in 10 ml of 0.1 N NaOH solution. The mixture was then placed in a water bath at 65°C for 6 hours. After cooling, the solution was centrifuged, and the supernatant was collected. Additionally, two separate test tubes received 0.1 ml aliquots of the sample solution. Each tube was diluted to a final volume of 1 ml with distilled water. A blank solution containing 1 ml of distilled water was also prepared in a separate test tube. To each tube, 5 ml of alkaline copper solution was added, and the mixture was allowed to mix at room temperature for 10 minutes. Subsequently, 0.5 ml of Folin-Ciocalteu reagent was added to each tube. After 30 minutes, the absorbance of the solutions was measured at 660 nm using a UV-

Visible spectrophotometer (Thermo Scientific, GENESYS 50). Finally, the amount of true protein was determined by constructing a standard graph using Bovine Serum Albumin (BSA) as the reference standard.

True Protein (%) =

$$\frac{\text{Graph factor } (\mu\text{g}) \times \text{Optical density} \times \text{Dilution factor} \times \text{Total vol. (ml)} \times 10^{-6}}{\text{Sample aliquot (ml)} \times \text{Weight of sample (g)}} \times 100 \quad \dots (3.11)$$

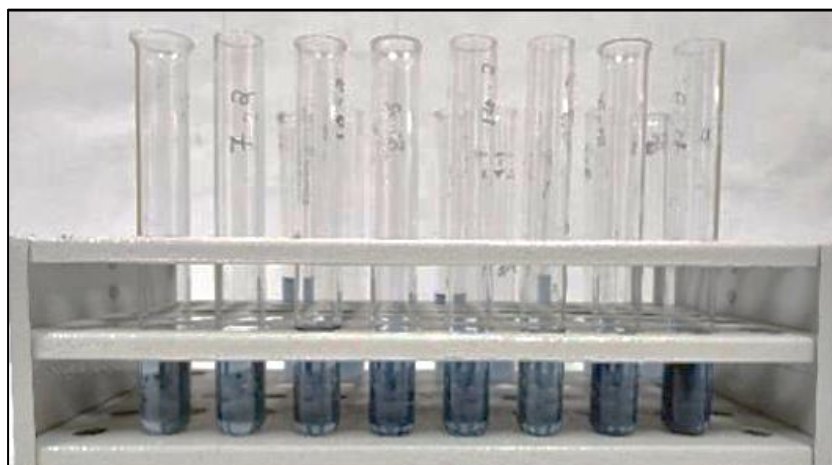


Plate 3.14 Determination of true protein content

3.9.3 Total oil content

The determination of the total oil content in the sample was conducted using an automated solvent extraction system following the AOAC (Association of Official Agricultural Chemists) method from 2012 (AOAC, 2012b). Approximately 2 g of the sample weighed transferred into a thimble made of Whatman No. 41 filter paper. Care was taken to avoid any powder adherence during the transfer. A pre-weighed solvent flask was attached to the thimble. Then, approximately 80 ml of petroleum ether with a boiling point range of 40-60°C was added to the flask containing the thimble and sample. The thimble, along with the flask, was placed inside the automated solvent extraction system. The system was programmed to perform two runs. After connecting the condenser, the first program was initiated, which involved maintaining a temperature of 100°C for 60 minutes. This allowed the petroleum ether to boil, evaporate, and subsequently condense back into the flask. Once the programmed time was completed, the valve controlling the flow of condensed ether to the flask was closed, and the second program was initiated. The second program involved maintaining a temperature of 200°C for 30 minutes, allowing the petroleum ether to boil, evaporate, and collect in the condenser, from where it could be further collected

in a separate container. Upon completion of the specified time, the flask was disconnected from the system and placed in an oven set to 105°C to evaporate any remaining excess ether. As a result, the residue remaining in the flask represented the total oil collected from the sample. The flask containing the oil was then re-weighed, and the amount of oil present in the sample was determined by subtracting the initial weight of the flask. The calculation was performed with an accuracy of 0.001 g. Finally, the percent total oil content was calculated using the following formula.

$$\text{Total oil (\%)} = \frac{(\text{Weight of flask + oil (g)} - (\text{Weight of empty flask (g)}))}{\text{Weight of sample (g)}} \times 100 \quad \dots (3.12)$$



Plate 3.15 Determination of total oil content

3.9.4 Total ash content

To determine the ash content, a crucible was filled with 2 grams of turmeric powder. The crucible was then placed inside a muffle furnace (Meta Instruments, Mumbai) at a temperature of 550°C. The heating continued until a constant weight of grey-colored ash was achieved. After a brief cooling period, the weights were recorded following the procedure outlined in AOAC (2012b). The ash content of turmeric powder was then calculated by,

$$\text{Total Ash (\%)} = \frac{\text{Weight of Ash (g)}}{\text{Weight of Sample (g)}} \times 100 \quad \dots (3.13)$$



Plate 3.16 Determination of total ash content

3.9.5 Total phenol content

The phenol content was determined using the method described by Malick and Singh (1980). A sample weighing approximately 0.1 grams was extracted with 10 ml of 80% ethanol. The mixture was then subjected to centrifugation, and the supernatant was collected. Next, 0.1 ml of the extracted solution was transferred to a test tube. The volume in each tube was adjusted to 3 ml using distilled water. Additionally, a test tube containing 3 ml of distilled water served as the blank solution. To each tube, including the blank, 0.5 ml of Folin-Ciocalteu reagent was added. After three minutes, 2 ml of 20% Na₂CO₃ solution was added to each tube. The solutions were thoroughly mixed and placed in a boiling water bath for exactly one minute. Following the heating step, the solutions were cooled to room temperature, and the color was measured at 650 nm using a UV-Visible spectrophotometer (Thermo Scientific, GENESYS 50). At last, the percentage of total phenol was calculated by preparing a standard curve of catechol. The following formula was used

$$\text{Total phenol (\%)} = \frac{\text{Graph factor } (\mu\text{g}) \times \text{Optical density} \times \text{Total vol. (ml)}}{\text{Sample aliquot (ml)} \times \text{Weight of sample (g)} \times 1000} \times 100 \quad \dots (3.14)$$

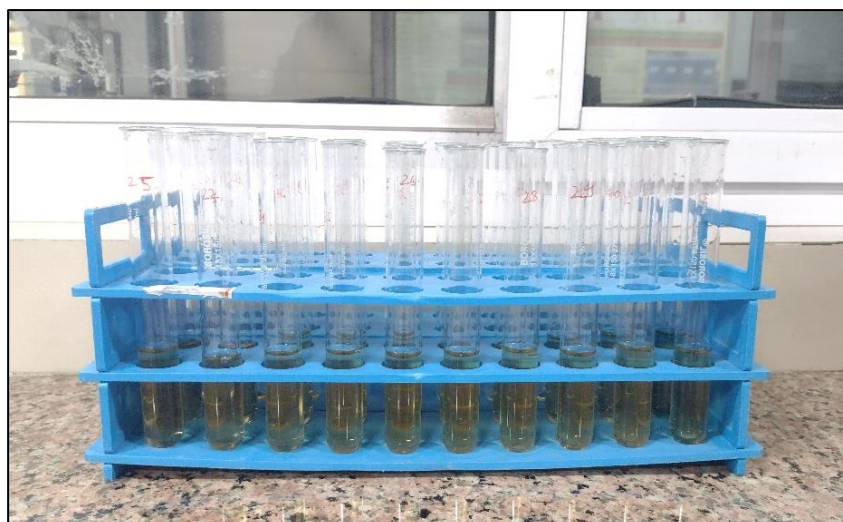


Plate 3.17 Determination of total phenol content

3.9.6 Antioxidant activity

The antioxidant activity was assessed using the DPPH free radical scavenging method as outlined by Chandra Shekhar and Anju (2014). A sample weighing approximately 0.1 grams was extracted with 10 ml of 90% methanol. In this procedure, a 0.012 gram of DPPH (2,2-diphenyl-1-picrylhydrazyl) was prepared in 100 ml distilled water using a volumetric flask. Subsequently, 1 ml of each diluted solution was transferred into separate test tubes, and 2 ml of the prepared DPPH solution was added to each tube. For the control sample, 2 ml of DPPH solution was added. A blank solution containing only DPPH solution was also prepared. The tubes were vigorously shaken and allowed to stand for 30 minutes at room temperature. Following the incubation period, the absorbance was measured at 517 nm using a UV-Visible spectrophotometer (Thermo Scientific, GENESYS 50).

The following formula was used to measure the percent DPPH scavenging effect.

$$\text{DPPH scavenging effect (\%)} = \frac{A_{\text{control}} - A_{\text{test}}}{A_{\text{control}}} \times 100 \quad \dots (3.15)$$

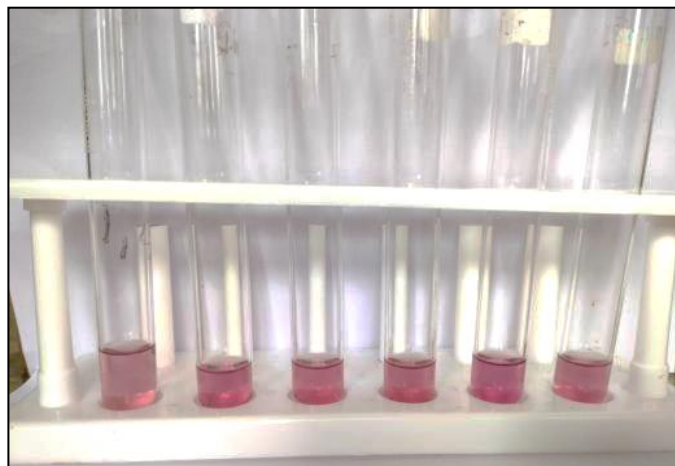


Plate 3.18 Determination of total antioxidant activity

3.9.7 Curcumin

Curcumin is quantitatively extracted by refluxing the material in alcohol and is estimated spectrometrically at 425 nm as per FSSAI, 2016. Dissolve 0.5 g of weighed, moisture-free turmeric powder in 250 ml of absolute methanol. Reflux the contents in the flask fitted with an air condenser over a heating mantle for 3-5 h, and compensate for alcohol loss if any due to evaporation by adding alcohol freshly into the flask. Cool and decant the extract into a volumetric flask and make up the volume. Dilute a suitable aliquot 1 ml to 10 ml with absolute methanol. Measure the intensity of the yellow color at 425 nm in a spectrophotometer and calculate curcumin content using the following formula.

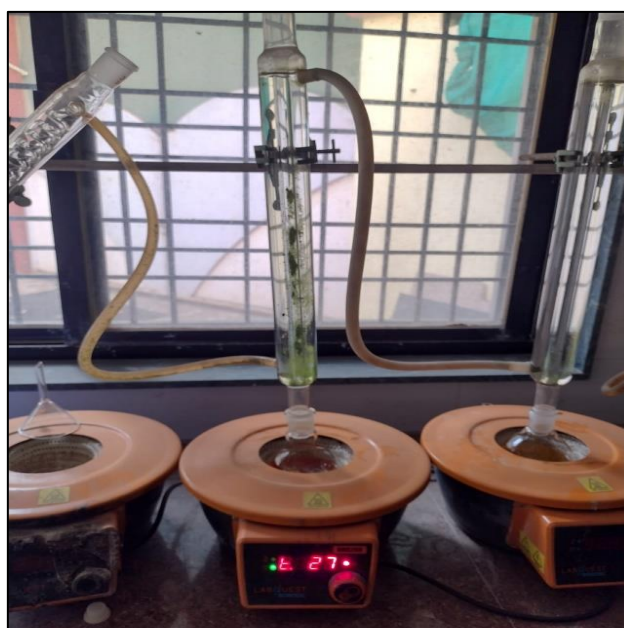


Plate 3.19 Determination of curcumin content

$$\text{Curcumin content } \left(\frac{\text{g}}{100\text{g}} \right) = \frac{0.0025 \times A_{425} \times \text{Volume (ml)} \times \text{Dilution factor} \times 100}{0.42 \times \text{Weight of the sample (g)} \times 1000} \dots (3.16)$$

3.9.8 Volatile oil

The hydro-distillation process was used to produce volatile oil yield (FSSAI, 2016). The equipment was cleaned with acetone and water before use and stored in a chromic-sulphuric acid solution. Before usage, it was fully washed. It was difficult to fully combine the powder and water in the instance of turmeric in a distillation flask. In the beginning, 1000 ml of distilled water and 50 g of sample were thoroughly combined in a container. The mixture was then carefully transferred to the 2-liter distillation flask. The major issue with the turmeric powder and water combination is the production of foam upon heating. A few shards of permeable earthenware were put into the mixture in the flask to confine it. The Clevenger device was then coupled to the flask on the heating mantle as seen in Plate 3.25. The condenser was tubed to the tap for the purpose of providing water. The device's collecting trap was filled with distilled water. Then, the flask was originally heated at a slightly higher temperature. A consistent temperature was kept for distillation once the temperature was lowered and the froth had settled. The apparatus was set in a way that did not allow condensate to drop directly on the surface of the liquid in the collecting trap but run down the side walls. The process was continued until two consecutive readings at an hour interval showed no change in the quantity of oil collected. At last, the volume of oil was read and the percentage was calculated by using the following formula.

$$\text{Volatile oil } \left(\% \frac{\text{v}}{\text{w}} \right) = \frac{\text{Volume of oil collected in trap (ml)}}{\text{Weight of sample taken (g)}} \times 100 \dots (3.17)$$



Plate 3.20 Determination of volatile oil content

3.10 Cost economics of turmeric drying by different methods

The cost economic analysis is carried out by considering fixed cost, variable cost and operational cost as per method suggested by Sahay (2006). The cost of drying turmeric by both solar tunnel drying and sun drying was carried out to suggest the best economical drying method.

3.11 Statistical analysis

The experimental data was be statistically analyzed used a Factorial Completely Randomized Design (FCRD) to determine the significance of various process parameters on the different responses. The analyzed was follow the techniques described by Panse and Sukhatme (1985), which are widely accepted in the field of agricultural statistics. This analysis was involved tests such as analyzed of variance (ANOVA) and post-hoc tests to identify significant effects and compare means between treatment groups. Overall, the FCRD approach and the techniques by Panse and Sukhatme was be used to conduct a comprehensive statistical analyzed of the data.

CHAPTER – IV

RESULTS AND DISCUSSION

The chapter entails result of the experiments carried out to meet the objectives of the present research problem. The study was initiated with the estimation of moisture content of raw turmeric rhizomes after cleaning thoroughly. It was followed by measurement of physical properties of rhizomes. After that the experiment was conducted as per explained in chapter - III. Further, quality of ground turmeric powder obtained through each treatment was assessed by estimating various biochemical parameters. The results obtained in each experiment of this study are presented and discussed in this chapter in due sequence.

4.1 Moisture content of raw turmeric rhizomes (*Salem*)

The values of moisture content of raw turmeric rhizomes, estimated as per the method described in Section 3.4 are shown in the following Table 4.1. The mean moisture content of raw turmeric rhizomes was found to be $78.25 \pm 0.703\%$ (wb).

Table 4.1 Moisture content of cleaned raw turmeric rhizomes (*Salem*)

| Moisture content % (wb) | | | | | Mean % (wb) | SD % (wb) |
|-------------------------|-------|-------|-------|-------|----------------|--------------|
| R-I | R-II | R-III | R-IV | R-V | | |
| 79.04 | 78.19 | 78.84 | 77.81 | 77.35 | 78.25 | 0.703 |

4.2 Physical properties of fresh turmeric rhizomes (*Salem*)

The mean values of the physical properties of fresh turmeric rhizomes at moisture content 78.25% (wb) are presented in Table 4.2 with their maximum, minimum and mean values.

4.2.1 Size

The size was determined from the measurement of length, breadth and thickness of 30 fresh turmeric rhizomes. The result of the size of fresh turmeric rhizomes is presented in Table 4.2. The size of rhizomes was varied from 18.52 to 38.31 mm with a mean value of 30.80 ± 4.82 mm.

4.2.2 Sphericity

The shape of 30 turmeric rhizomes could be expressed in terms of their sphericity. The result of the sphericity of fresh turmeric rhizomes is presented in Table 4.2. The sphericity of turmeric rhizomes was varied from 0.39 to 0.65 with a mean value of 0.48 ± 0.07 . The shape of fresh turmeric rhizome is classified as cylindrical shape as per the classification given by Mohsenin (1986).

4.2.3 Bulk density

The result of the bulk density of fresh turmeric rhizomes is presented in Table 4.2. The bulk density was varied from 426.94 to 453.64 kg/m³ with a mean value of 447.87 ± 10.61 kg/m³.

4.2.4 True density

The result of true density of fresh turmeric rhizomes are presented in Table 4.2. True density was varied from 1084.63 to 1177.65 kg/m³ with a mean value of and 1115.67 ± 36.97 kg/m³.

4.2.5 Porosity

The result of porosity of fresh turmeric rhizomes are presented in Table 4.2. The mean value of porosity was estimated at $60.22 \pm 1.02\%$.

Table 4.2 Physical properties of fresh turmeric rhizomes (*Salem*)

| Sr. | Parameter | Minimum | Maximum | Mean | SD |
|-----|---|---------|---------|---------|-------|
| 1 | Size, mm (n = 30) | 18.52 | 38.31 | 30.80 | 4.82 |
| 2 | Sphericity (n = 30) | 0.39 | 0.65 | 0.48 | 0.07 |
| 3 | Bulk density, kg/m ³ (n = 5) | 426.94 | 453.64 | 447.87 | 10.61 |
| 4 | True density, kg/m ³ (n = 5) | 1084.63 | 1177.65 | 1115.67 | 36.97 |
| 5 | Porosity, % (n = 5) | 59.03 | 61.48 | 60.22 | 1.02 |

4.3 Physical properties of solar tunnel dried and sun-dried turmeric rhizomes (*Salem*)

4.3.1 Size

The size was determined from the measurement of the length, breadth and thickness of dried turmeric rhizomes. The result of the size of dried turmeric rhizomes

are presented in Table 4.3. The mean size values for solar tunnel dried and sun-dried turmeric rhizomes were 16.56 ± 2.81 mm and 16.38 ± 2.80 mm, respectively.

4.3.2 Sphericity

The shape of turmeric rhizomes could be expressed in terms of their sphericity. The result of the sphericity of dried turmeric rhizomes is presented in Table 4.3. The mean sphericity values for solar tunnel dried and sun-dried turmeric rhizomes were 0.41 ± 0.02 % and 0.41 ± 0.02 %, respectively.

4.3.3 Bulk density

The result of the bulk density of dried turmeric rhizomes is presented in Table 4.3. The result of the size of dried turmeric rhizomes are presented in Table 4.3. The mean bulk density values for solar tunnel dried and sun-dried turmeric rhizomes were 579.15 ± 20.60 kg/m³, and 562.09 ± 18.42 kg/m³, respectively.

4.3.4 True density

The result of true density of dried turmeric rhizomes are presented in Table 4.3. The mean true density values for solar tunnel dried and sun-dried turmeric rhizomes were 1258.15 ± 61.82 kg/m³, and 1209.18 ± 49.74 kg/m³, respectively.

4.3.5 Porosity

The result of porosity of dried turmeric rhizomes are presented in Table 4.3. The mean porosity values for solar tunnel dried and sun-dried turmeric rhizomes were 54.40 %, and 53.51 %, respectively.

Table 4.3 Physical properties of dried turmeric rhizomes (*Salem*)

| Sr. No. | Parameter | Mean | |
|---------|---------------------------------|---------------------|---------------------|
| | | Solar tunnel dried | Sun dried |
| 1 | Size, mm | 16.56 ± 2.81 | 16.38 ± 2.80 |
| 2 | Sphericity | 0.41 ± 0.02 | 0.41 ± 0.02 |
| 3 | Bulk density, kg/m ³ | 579.15 ± 20.60 | 562.09 ± 18.42 |
| 4 | True density, kg/m ³ | 1258.15 ± 61.82 | 1209.18 ± 49.74 |
| 5 | Porosity, % | 54.40 | 53.51 |

4.4 Proximate composition of fresh turmeric rhizomes (Salem)

4.4.1 Moisture content

The moisture content of fresh turmeric rhizomes is presented in Table 4.4. The values of moisture content of raw turmeric rhizomes, estimated as per section 3.4 are shown in Table 4.1. The mean value of moisture was estimated at $78.25 \pm 0.703\%$ (wb).

4.4.2 Total carbohydrate

The values of total carbohydrate of raw turmeric rhizomes, estimated as per section 3.9.1. The total carbohydrate of fresh turmeric rhizomes is presented in Table 4.4. The mean value of total carbohydrate was estimated at $9.18 \pm 0.38\%$.

4.4.3 True protein

The values of true protein of raw turmeric rhizomes, estimated as per section 3.9.2. The true protein of fresh turmeric rhizomes is presented in Table 4.4. The mean value of true protein was estimated at $1.41 \pm 0.08\%$.

4.4.4 Total oil

The values of total oil of raw turmeric rhizomes, are estimated as per section 3.9.3. The total oil of fresh turmeric rhizomes is presented in Table 4.4. The mean value of total oil was estimated at $0.82 \pm 0.11\%$.

4.4.5 Total ash

The values of total ash of raw turmeric rhizomes are estimated as per section 3.9.4. The total ash of fresh turmeric rhizomes is presented in Table 4.4. The mean value of total ash was estimated at $0.71 \pm 0.18\%$.

Table 4.4 Proximate composition of fresh turmeric rhizomes

| Sr. | Parameters | Mean \pm SD (n=3) |
|-----|--------------------------|---------------------|
| 1 | Moisture content, % (wb) | 78.25 ± 0.703 |
| 2 | Total carbohydrate, % | 9.18 ± 0.38 |
| 3 | True protein, % | 1.41 ± 0.08 |
| 4 | Total oil, % | 0.82 ± 0.11 |
| 5 | Total ash, % | 0.71 ± 0.18 |

4.5 Moisture content of blanched turmeric % (wb)

The variation in moisture content with blanching temperatures, times and thicknesses of a sample given in APPENDIX-A4. It was observed that the initial moisture content of the turmeric was slightly lower in comparison with blanched samples. The increased moisture content was recorded as 2 to 3% (wb) in a blanched sample. Kachhadiya *et al.* (2018) observed similar relationships while blanching significantly increased moisture content from 76% to 80.2% (wb).

4.6 Performance Evaluation of Solar Tunnel Dryer under drying of turmeric (February to March, 2023)

The solar tunnel dryer environment in terms of diurnal variation of inside air, temperature, relative humidity and solar radiation, was measured for the time interval of 1 h for the month of February to March 2023 and average data are discussed here under.

4.6.1 Diurnal Variation of Solar Tunnel Dryer Environment

1) Temperature

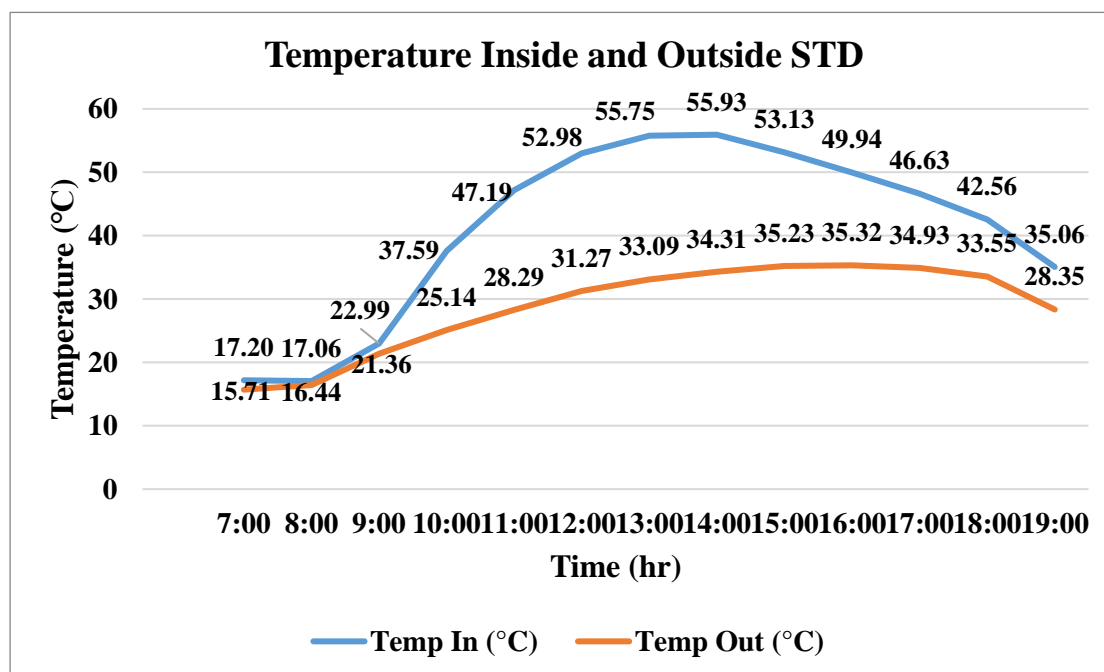


Fig.4.1 Effect in temperature during month of February-2023 inside and outside of STD

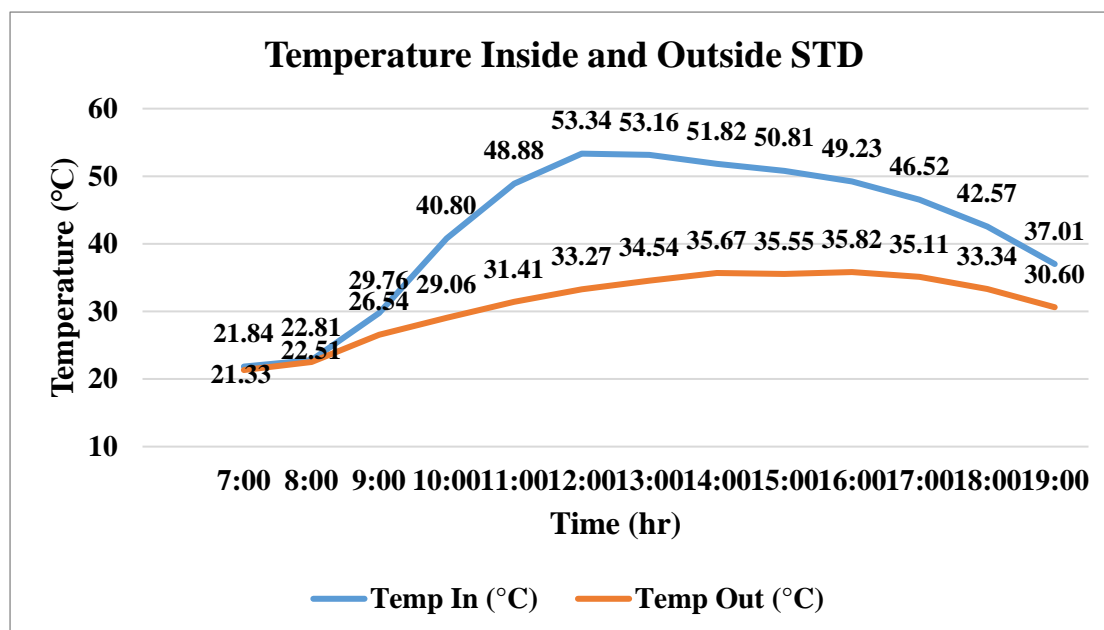


Fig. 4.2 Effect in temperature during the month of March 2023 inside and outside of STD

The daytime temperature variation for the month, that is, February to March 2023, the minimum temperature recorded was 17.06°C and the maximum was 55.93°C inside of dryer. Similarly, outside the dryer, temperature also experienced variations, with the recorded temperature levels ranging from a minimum of 15.71°C to a maximum of 35.67°C. The inside temperature of STD was higher as compared to the outside ambient temperature.

2) Solar Insolation

The daytime Solar Insolation variation for the month, that is, February to March 2023, the minimum of solar insolation recorded was 0 W/m² and the maximum was 520.43 W/m² inside of dryer. Similarly, outside the dryer, Solar Insolation also experienced variations, with the recorded Solar Insolation levels ranging from a minimum of 0 W/m² to a maximum of 901.99 W/m². Solar Insolation Inside the STD was lower as compared to outside ambient Solar Insolation from 8:00 AM to 7:00 PM.

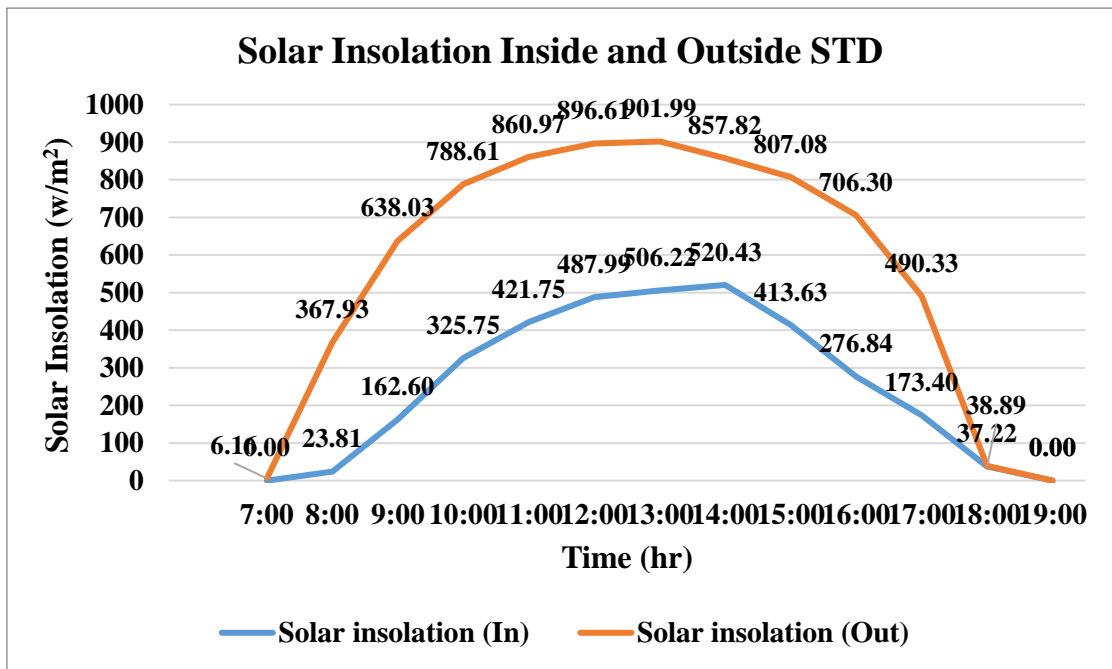


Fig.4.3 Effect in solar insolation during the month of February 2023 inside and outside of STD

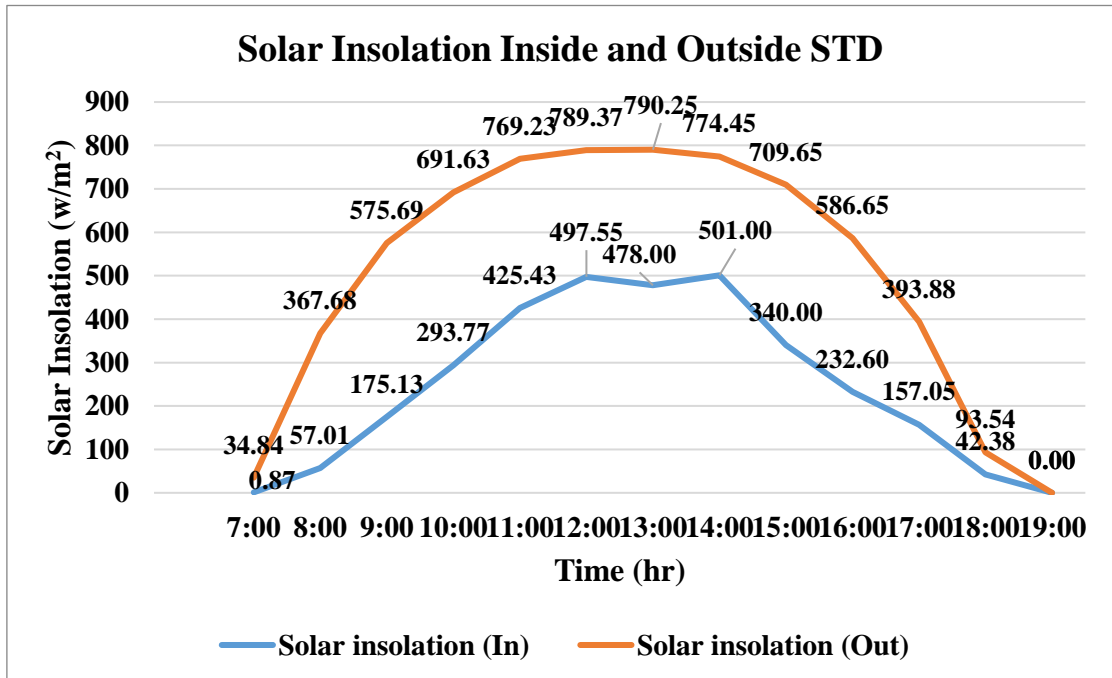


Fig.4.4 Effect in solar insolation during the month of March 2023 inside and outside of STD

3) Humidity

The daytime Humidity variation for the month, that is February to March 2023, the minimum Humidity recorded was 8.17% and the maximum was 66.67% inside of dryer. Similarly, outside the dryer, the humidity also experienced variations, with the recorded humidity levels ranging from a minimum of 18.89% to a maximum of 78.91%.

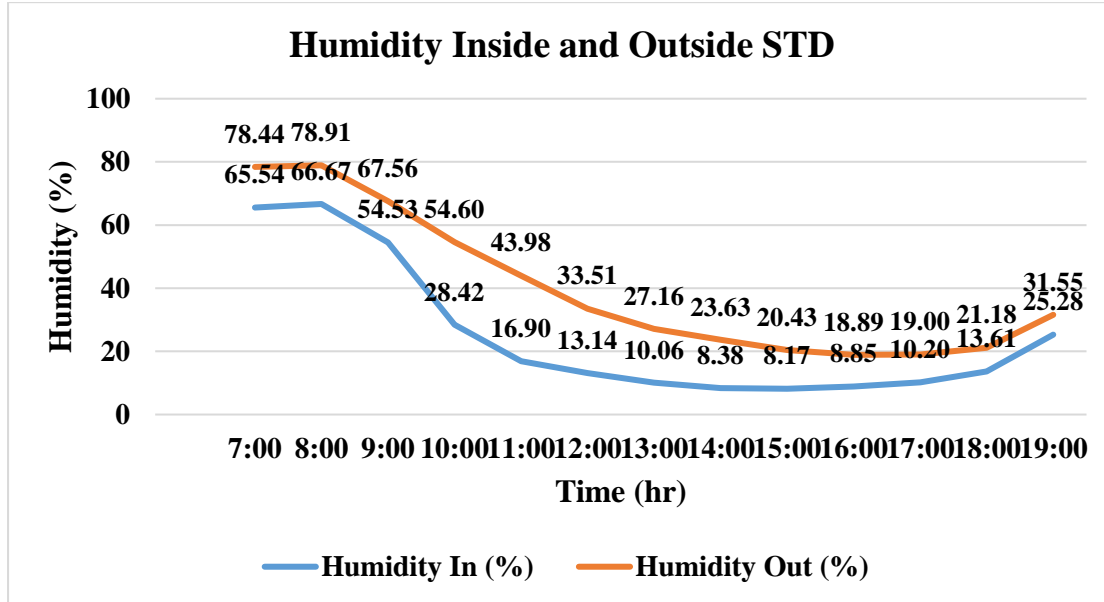


Fig.4.5 Effect in humidity during the month of February 2023 inside and outside of STD

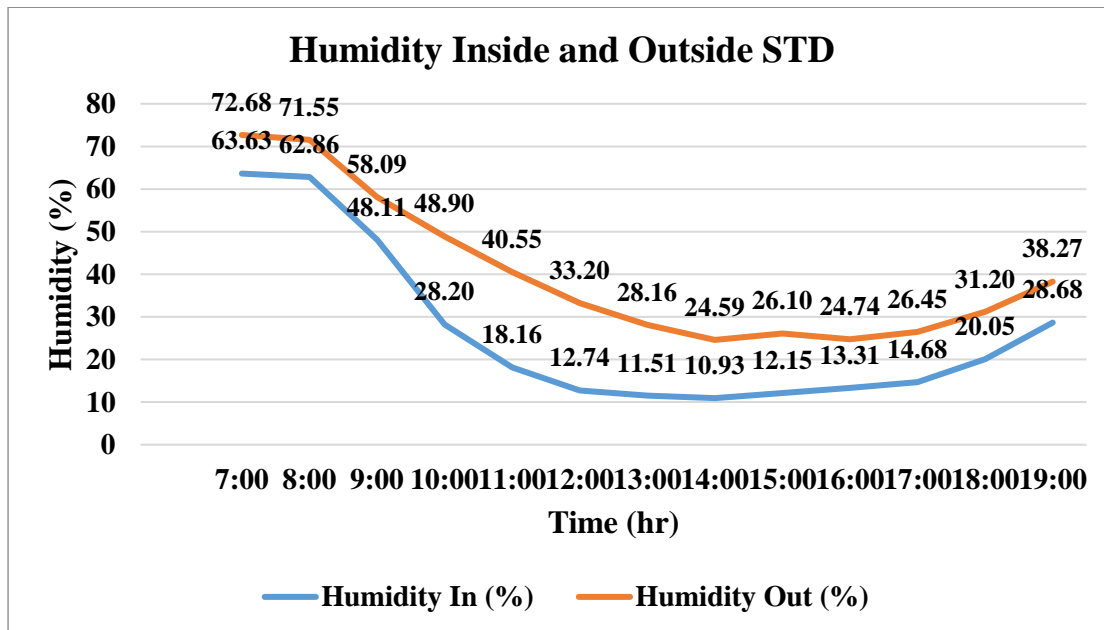


Fig.4.6 Effect in humidity during the month of March 2023 inside and outside of STD

4.7 Drying characteristics

4.7.1 Experiment 1: Drying of turmeric rhizomes by solar tunnel dryer

4.7.1.1 Drying characteristics of blanched whole and sliced turmeric at 70°C

The details of treatment combinations are given in Table 3.2(a) of Chapter III.

1) The moisture content of blanched sliced and whole turmeric vs. drying time

The moisture content of samples during solar tunnel drying of turmeric is given in APPENDIX-B1 as well a graphical representation of moisture content with respect to drying time is illustrated in Fig. 4.7 to Fig. 4.9. It was observed that the turmeric blanched at 70°C for 45 min, rate of moisture removal was faster in 4 mm, 5 mm and whole turmeric results in lower drying time, i.e., 6, 6 and 19 days, respectively. Followed by turmeric blanched at 70°C for 30 min and higher drying times at 70°C for 15 min treatments. This shows as the blanching time increased at constant blanching temperature (70°C), drying time decreased proportionately.

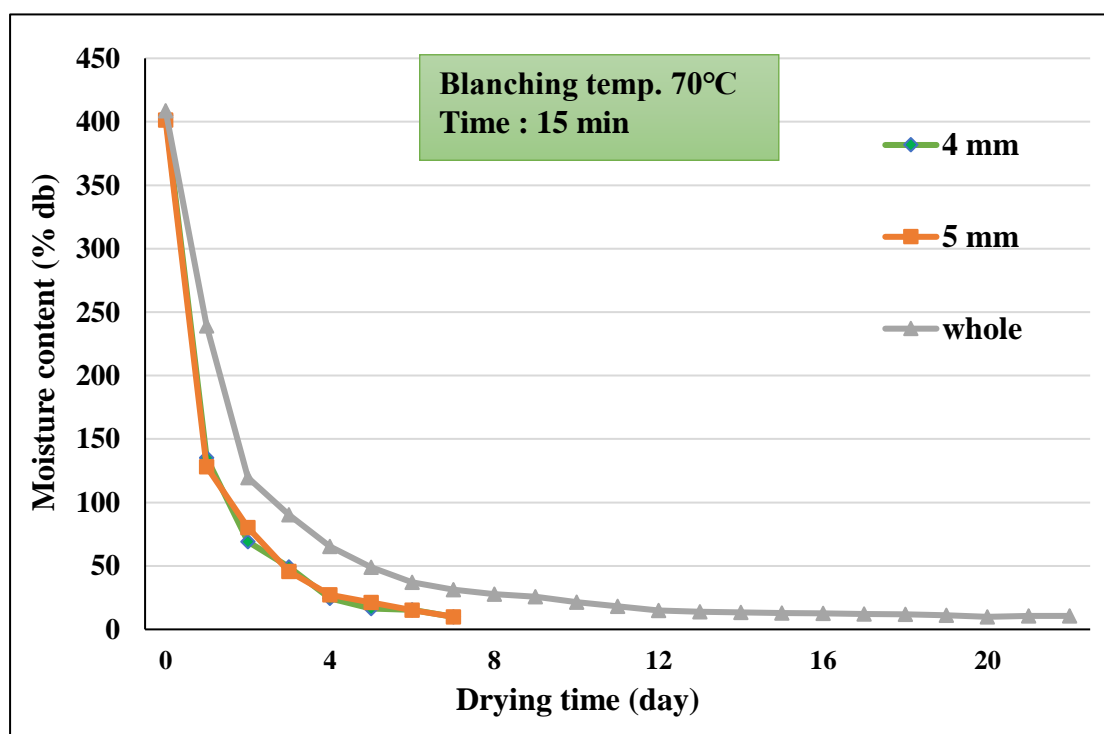


Fig. 4.7 Effect in the moisture content with drying time of turmeric blanched at 70°C for 15 min using solar tunnel drying

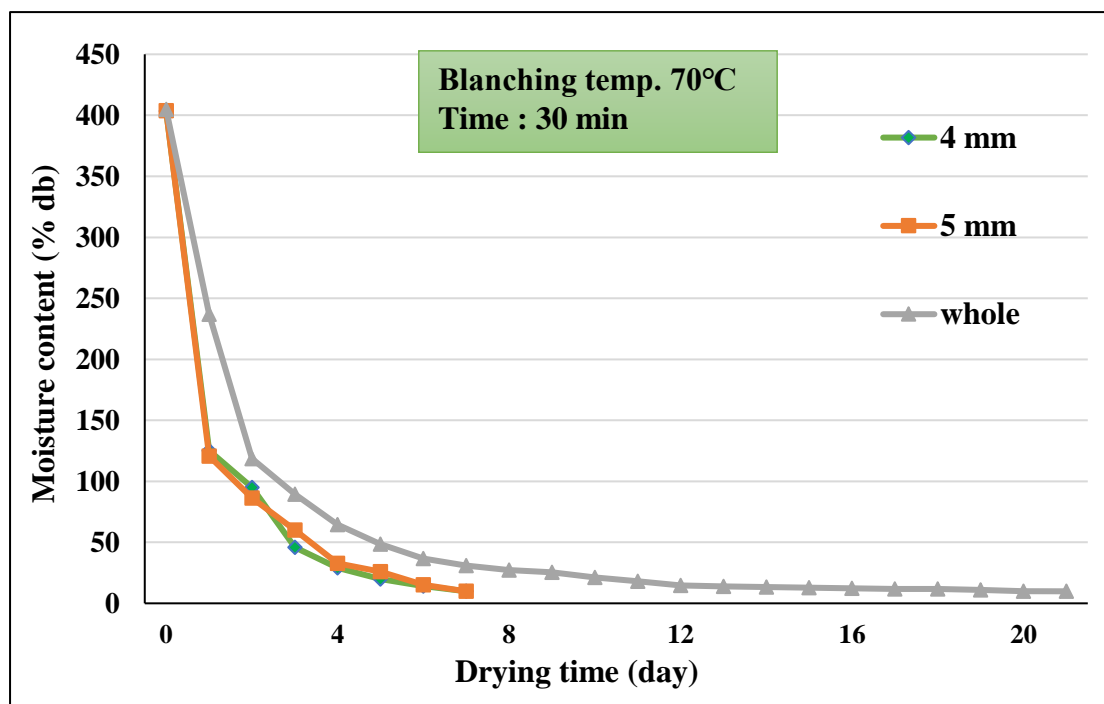


Fig.4.8 Effect in the moisture content with drying time of turmeric blanching at 70°C for 30 min using solar tunnel drying

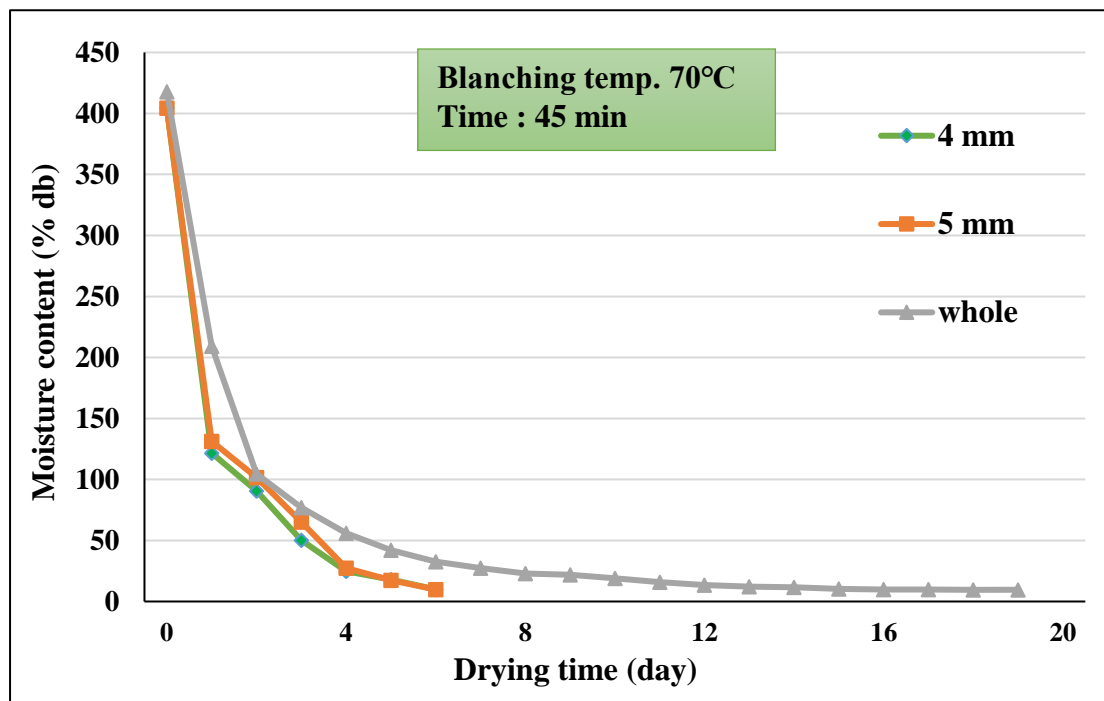


Fig. 4.9 Effect in the moisture content with drying time of turmeric blanching at 70°C for 45 min using solar tunnel drying

The relationship between moisture content and drying time was determined to be non-linear, in the initial stage of drying showing a larger decrease in moisture compared to the later stages. Similar type of trends was also observed for other blanching treatment as shown in Fig. 4.7, 4.8, and 4.9. It was observed that the moisture content reduction was relatively higher for treatment B₁M₃S₁D₁ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-4 mm) and B₁M₃S₂D₁ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-5 mm) as compared to B₁M₁S₃D₁ (Blanching temperature-70°C, Blanching time-15 min, and Slice thickness-whole). While the drying time variations were almost similar for the B₁M₃S₁D₁ and B₁M₃S₂D₁ treatments, the B₁M₁S₃D₁ treatment showed the longest duration for the drying process.

The turmeric in the solar tunnel dryer dried at a faster rate compared to open sun drying. The turmeric in the solar dryer dried at a faster rate mainly due to the higher temperature achieved in the dryer which causes higher diffusion of moisture from the interior to the surface of turmeric as compared to turmeric dried in ambient conditions (Gill *et al.*, 2021).

2) Drying rate of blanched sliced and whole turmeric vs. drying time

The drying rate of samples during solar tunnel drying of turmeric is given in APPENDIX-B2 as well a graphical representation of the drying rate with respect to drying time is illustrated in Fig. 4.10 to Fig. 4.12. The relationship between drying rate and drying time was determined to be non-linear, with the initial stage of drying showing a decrease in rates compared to the later stages of drying. Similar types of trends were also observed for other blanching treatments as shown in Fig. 4.10, 4.11, and 4.12. It was observed that the drying rate increased was relatively higher for treatment B₁M₃S₂D₁ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-5 mm) and B₁M₃S₁D₁ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-4 mm) in comparison to B₁M₁S₃D₁ (Blanching temperature-70°C, Blanching time-15 min, and Slice thickness-whole). It was observed that drying rates increased with a decrease in slice thickness of turmeric.

Drying of sliced rhizomes showed better drying rate and effective drying time can be reduced by slicing instead of drying in whole form. Sliced samples showed more uniform falling in comparison to that of whole rhizomes.

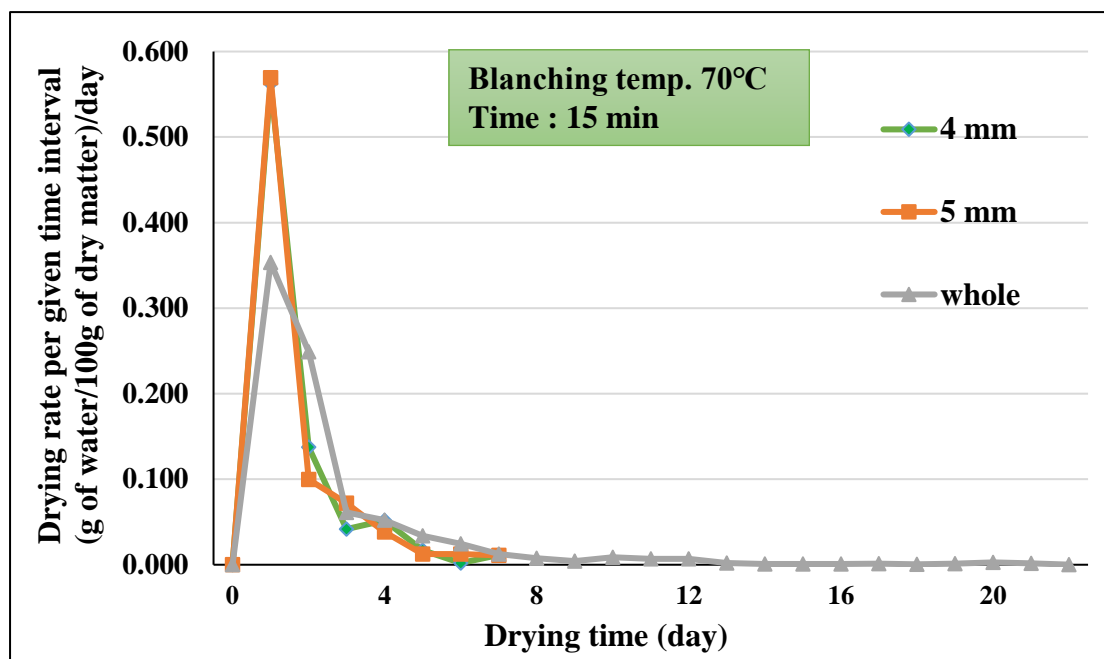


Fig. 4.10 Effect in the drying rate with drying time of turmeric blanching at 70°C for 15 min using solar tunnel drying

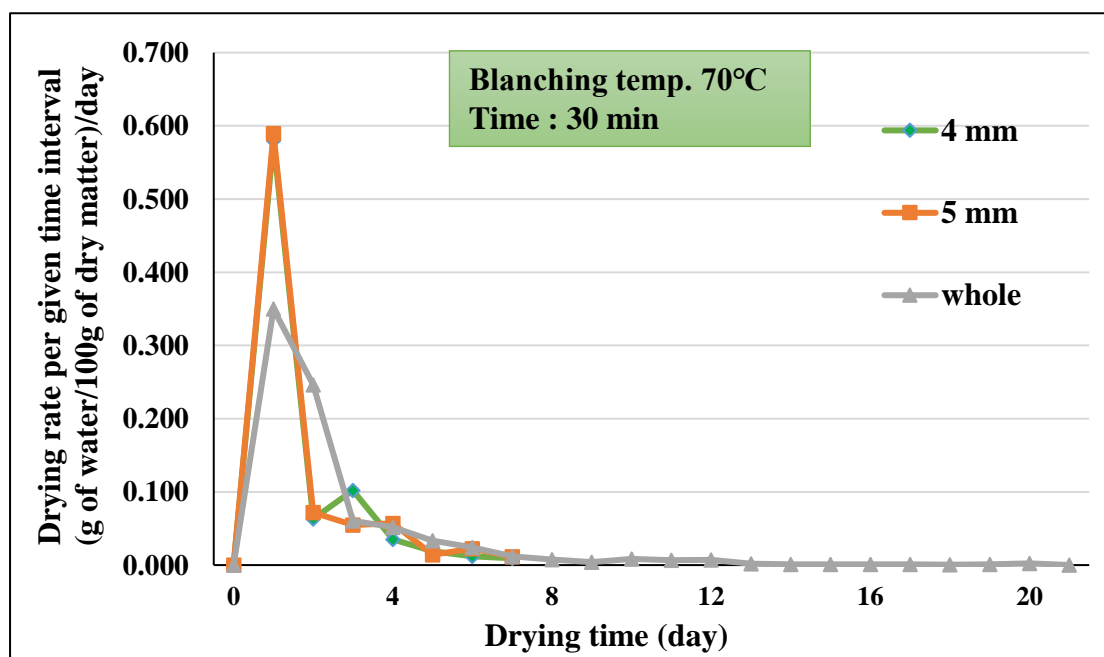


Fig.4.11 Effect in the drying rate with drying time of turmeric blanching at 70°C for 30 min using solar tunnel drying

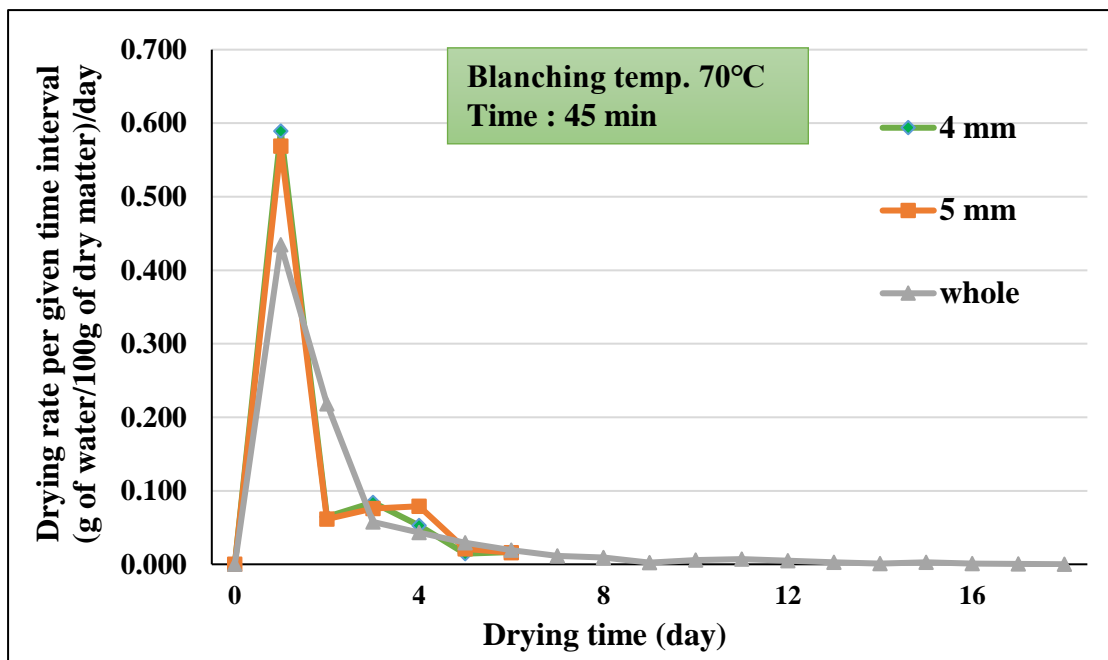


Fig.4.12 Effect in the drying rate with drying time of turmeric blanching at 70°C for 45 min using solar tunnel drying

The drying rate was higher during the initial period but as the drying progressed, the drying rate decreased gradually. This is due to more evaporation of moisture from the surface and later, the rate of moisture removal decreases mainly due to diffusion of moisture from the interior to the surface of turmeric. The faster drying of hydrothermally pretreated turmeric was because pores open up during the boiling of turmeric allowing faster flow of moisture to the surface (Velappan *et al.*, 1993).

3) Moisture ratio (MR) of blanched sliced and whole turmeric vs. drying time

The moisture ratio of samples during solar tunnel drying of turmeric is given in APPENDIX-B3 as well a graphical representation of moisture ratio (MR) with respect to drying time is illustrated in Fig. 4.13 to Fig. 4.15. The moisture ratio of blanched turmeric slices and whole was decreased exponentially with the drying time. In the initial stage, the moisture ratio dropped faster and it slowed down in the later stages of drying irrespective of treatments (Velappan *et al.*, 1993).

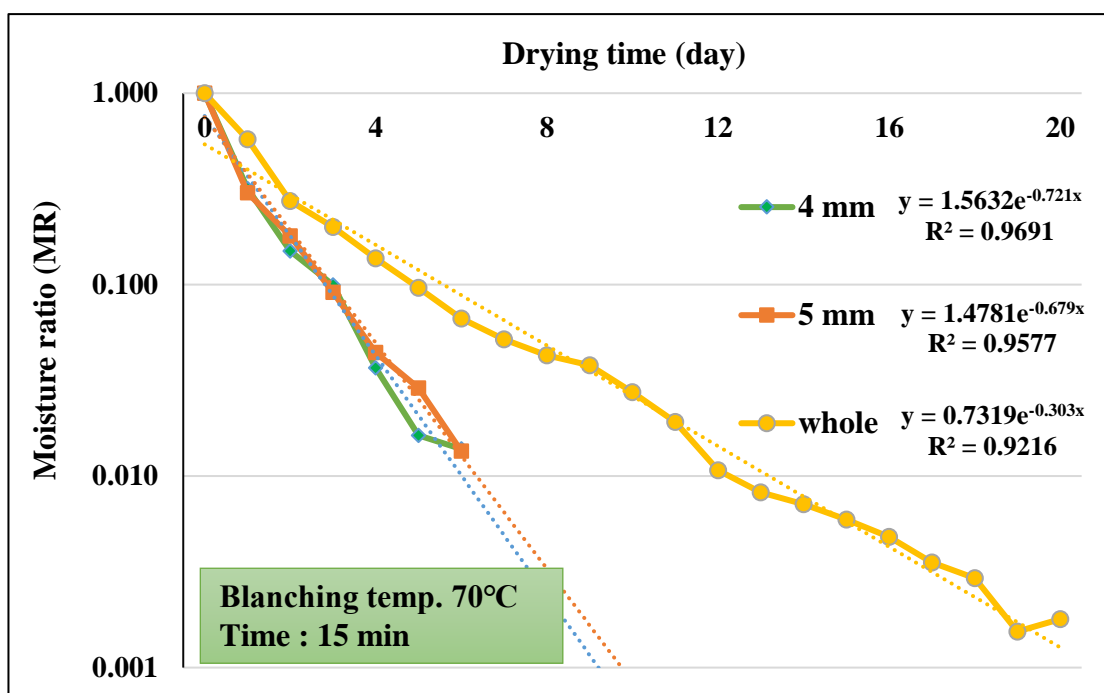


Fig. 4.13 Effect in the moisture ratio with drying time of turmeric blanching at 70°C for 15 min using solar tunnel drying

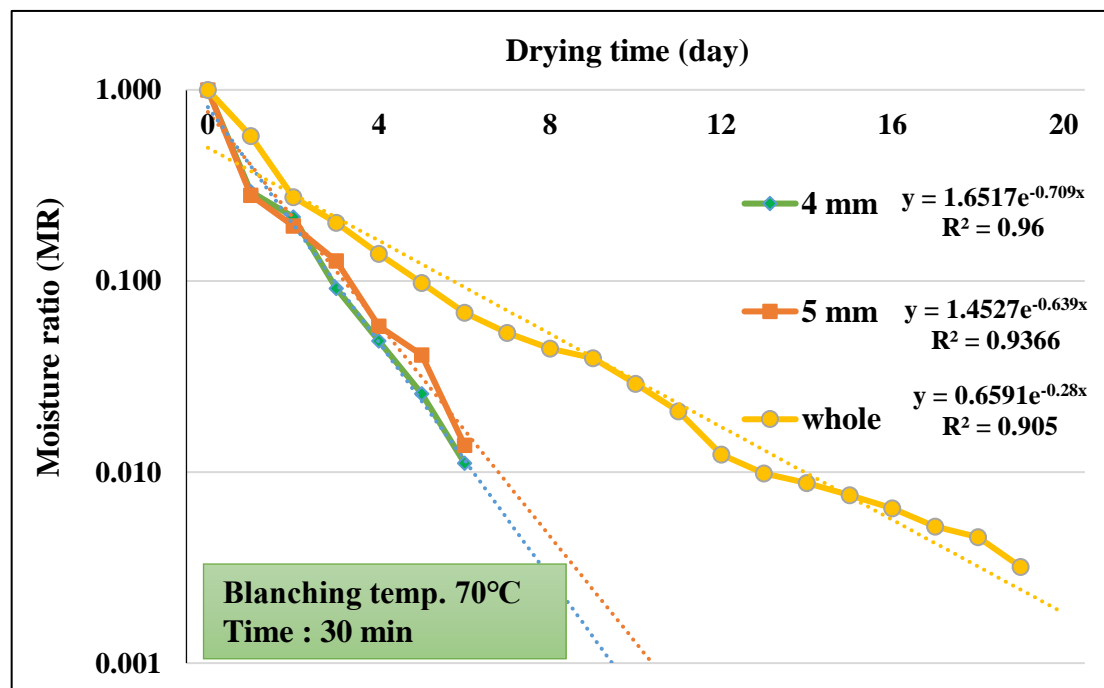


Fig. 4.14 Effect in the moisture ratio with drying time of turmeric blanching at 70°C for 30 min using solar tunnel drying

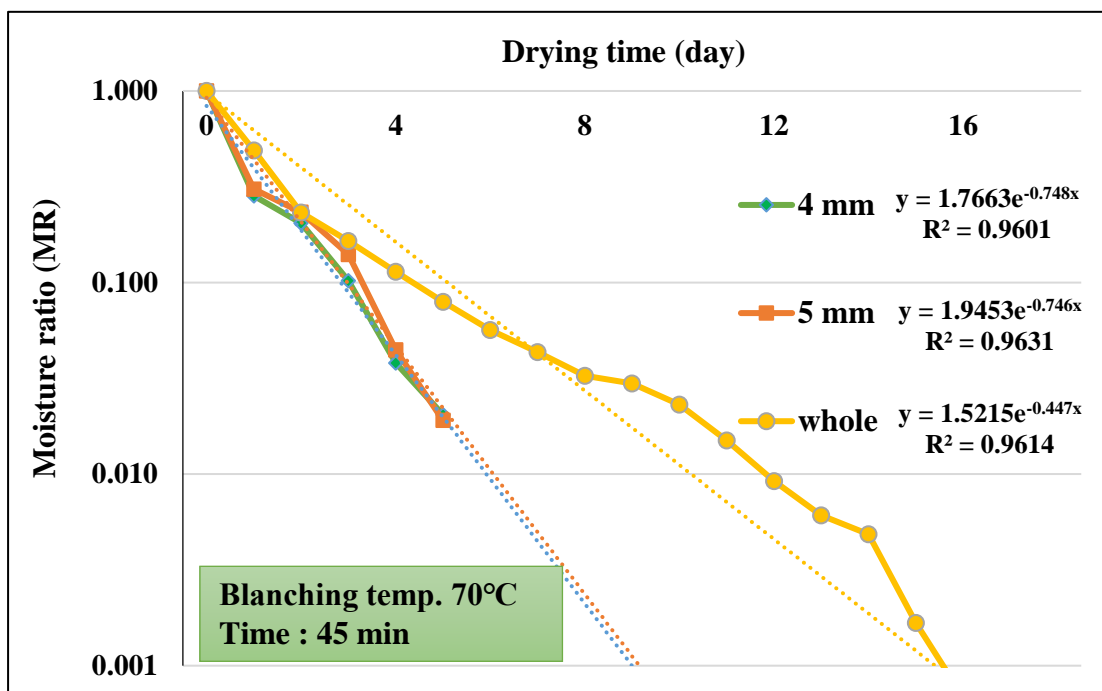


Fig. 4.15 Effect in the moisture ratio with drying time of turmeric blanching at 70°C for 45 min using solar tunnel drying

This observation is evident from Figures Fig. 4.13 to Fig. 4.15. Notably, the lower moisture ratios were observed in the treatment $B_1M_3S_1D_1$ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-4 mm) and $B_1M_3S_2D_1$ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-5 mm) while the higher moisture ratios were observed in the treatment $B_1M_1S_3D_1$ (Blanching temperature-70°C, Blanching time-15 min, and Slice thickness-whole). While the moisture rate variations were almost similar for the $B_1M_3S_1D_1$ and $B_1M_3S_2D_1$ treatments, the $B_1M_1S_3D_1$ treatment showed the higher moisture ratios duration for the drying process. The results indicate that the moisture ratios of whole rhizomes are influenced by the blanching time and temperature, with lower blanching temperatures and shorter blanching times resulting in higher moisture ratios. This was observed in turmeric samples with lower slice thickness and higher blanching temperatures showing lower moisture ratios.

4) Treatments of blanched sliced and whole turmeric vs. drying time

The drying time for the different samples of blanched turmeric slices and whole is given in APPENDIX-B1 and the comparative view of drying time for the different

treatments is graphically presented in Fig. 4.16. The maximum drying time was recorded as 22 days in treatment B₁M₁S₃D₁ (Blanching temperature = 70°C, Blanching time = 15 min, and Slice thickness = whole). While, the minimum drying time was found 6 days in treatment B₁M₃S₁D₁ (Blanching temperature = 70°C, Blanching time = 45 min, and Slice thickness = 4 mm) and B₁M₃S₂D₁ (Blanching temperature = 70°C, Blanching time = 45 min, and Slice thickness = 5 mm).

It was observed that blanching time and temperature significantly affected the drying time. As the blanching time and temperature increased the drying time decreased. Blanching for a longer duration softens the tissues and enhances the removal of water at a faster rate thus reduced the drying time (Jayashree and Zachariah 2018).

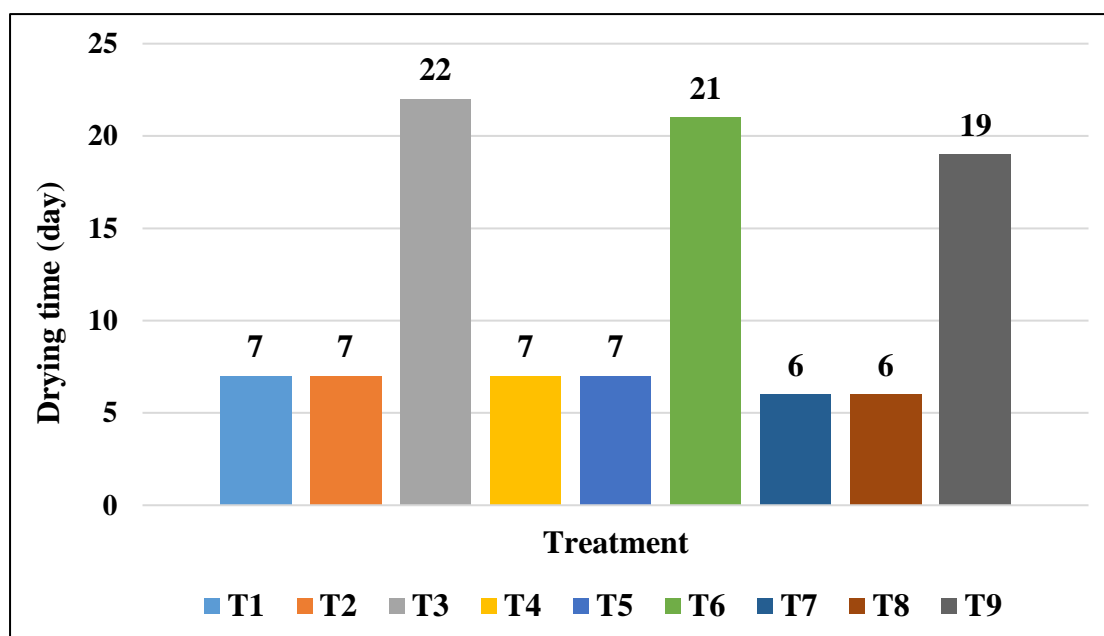


Fig. 4.16 Treatments with drying time during solar tunnel drying

4.7.1.2 Drying characteristics of blanched whole and sliced turmeric at 80°C

The details of treatment combinations are given in Table 3.2(a) of Chapter III.

1) Moisture content of blanched sliced and whole turmeric vs. drying time

The moisture content of samples during solar tunnel drying of turmeric is given in APPENDIX-C1 as well a graphical representation of moisture content with respect to drying time is illustrated in Fig. 4.17 to Fig. 4.19.

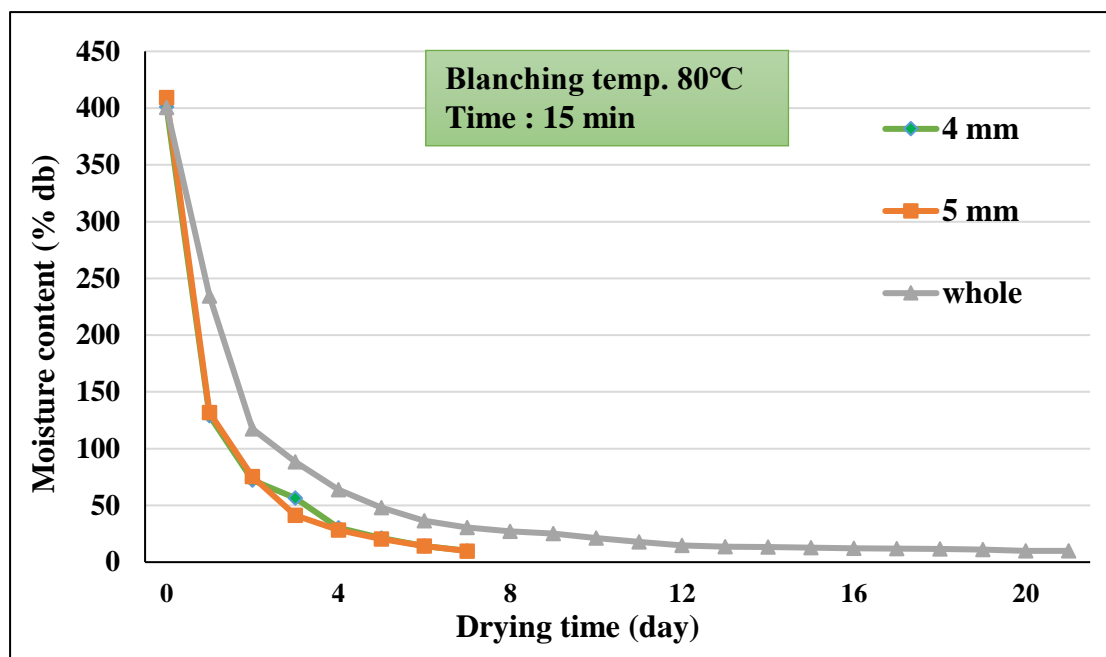


Fig.4.17 Effect in the moisture content with drying time of turmeric blanching at 80°C for 15 min using solar tunnel drying

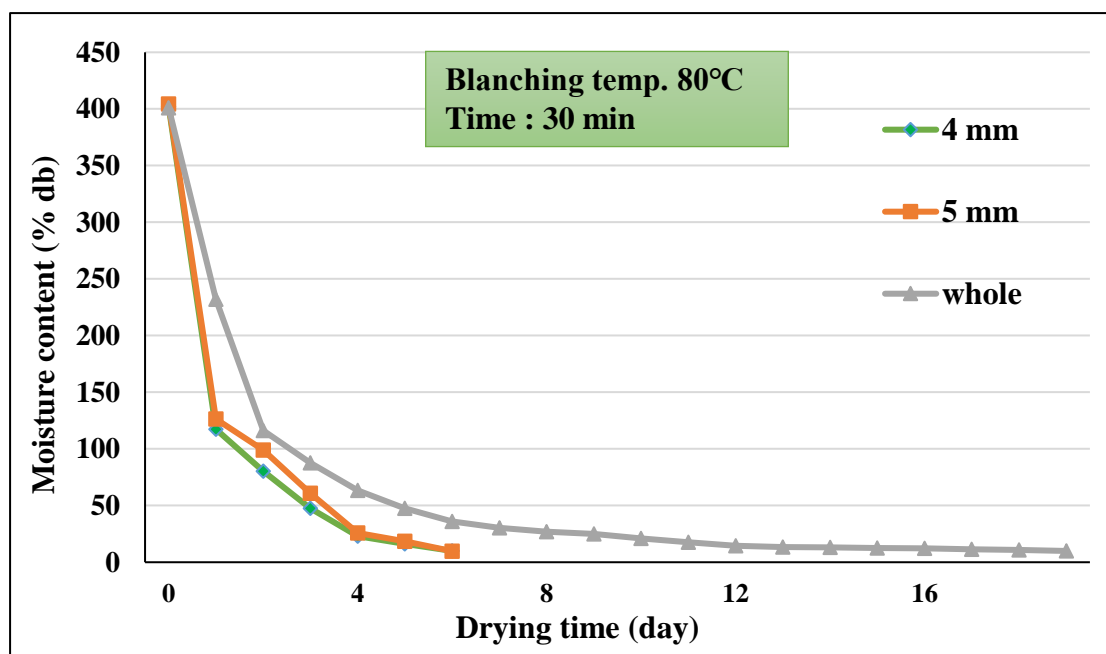


Fig.4.18 Effect in the moisture content with drying time of turmeric blanching at 80°C for 30 min using solar tunnel drying

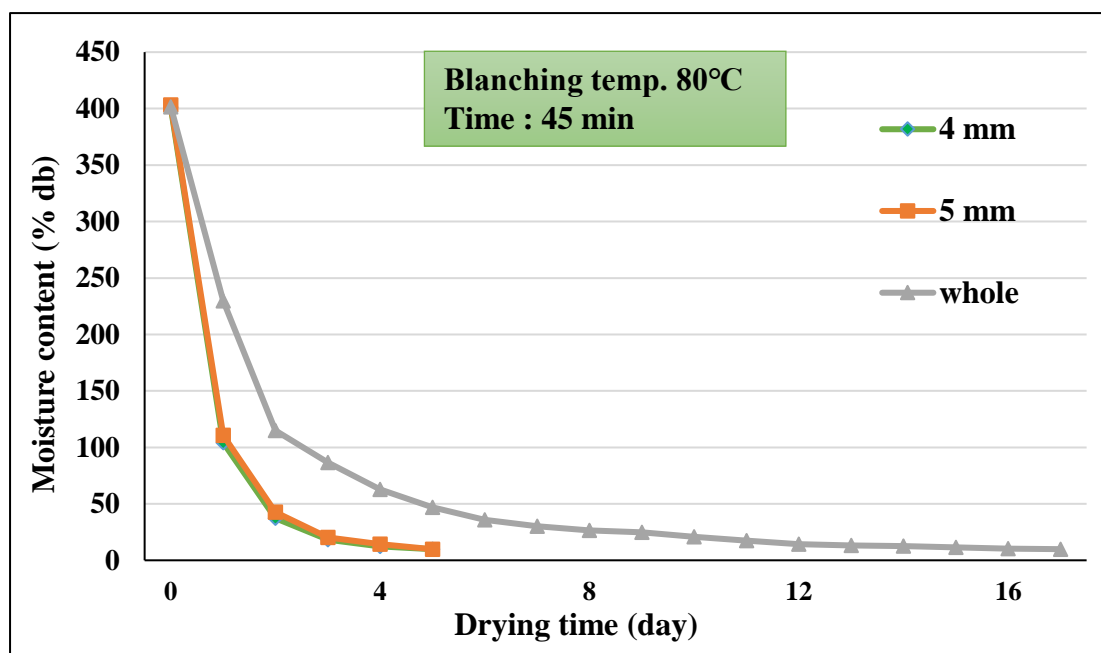


Fig. 4.19 Effect in the moisture content with drying time of turmeric blanched at 80°C for 45 min using solar tunnel drying

The relationship between moisture content and drying time was determined to be non-linear, in the initial stage of drying showing a larger decrease in moisture compared to the later stages. Similar type of trends was also observed for other blanching treatment as shown in Fig. 4.17 to Fig. 4.19. It was observed that the moisture content reduction was relatively higher for treatment B₂M₃S₁D₁ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-4 mm) and B₂M₃S₂D₁ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-5 mm) in comparison to B₂M₁S₃D₁ (Blanching temperature-80°C, Blanching time-15 min, and Slice thickness-whole). While the drying time variations were almost similar for the B₂M₃S₁D₁ and B₂M₃S₂D₁ treatments, the B₂M₁S₃D₁ treatment showed the longest duration for the drying process.

It was observed that the turmeric blanched at 80°C for 45 min, the rate of moisture removal was faster at 4 mm, 5 mm and whole turmeric resulted in lower drying time, i.e., 5, 5 and 17 days, respectively. Followed by turmeric blanched at 80°C for 30 min and higher drying times at 80°C for 15 min treatments. This shows as the blanching time increased at constant blanching temperature (80°C), drying time decreased proportionately.

The turmeric in the solar tunnel dryer dried at a faster rate compared to open sun drying. The turmeric in the solar dryer dried at a faster rate mainly due to the higher temperature achieved in the dryer which causes higher diffusion of moisture from the interior to the surface of turmeric as compared to turmeric dried in ambient conditions (Gill *et al.*, 2021).

2) Drying rate of blanched sliced and whole turmeric vs. drying time

The drying rate of samples during solar tunnel drying of turmeric is given in APPENDIX-C2 as well a graphical representation of the drying rate with respect to drying time is illustrated in Fig. 4.20 to Fig. 4.22. The relationship between drying rate and drying time was determined to be non-linear, with the initial stage of drying showing a decrease in rates compared to the later stages of drying. Similar types of trends were also observed for other blanching treatments as shown in Fig. 4.20 to Fig. 4.22. It was observed that the drying rate increase was relatively higher for treatment B₂M₃S₁D₁ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-4 mm) and B₂M₃S₂D₁ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-5 mm) in comparison to B₂M₁S₃D₁ (Blanching temperature-80°C, Blanching time-15 min, and Slice thickness-whole). It was observed that drying rates increased with a decrease slice thickness of turmeric.

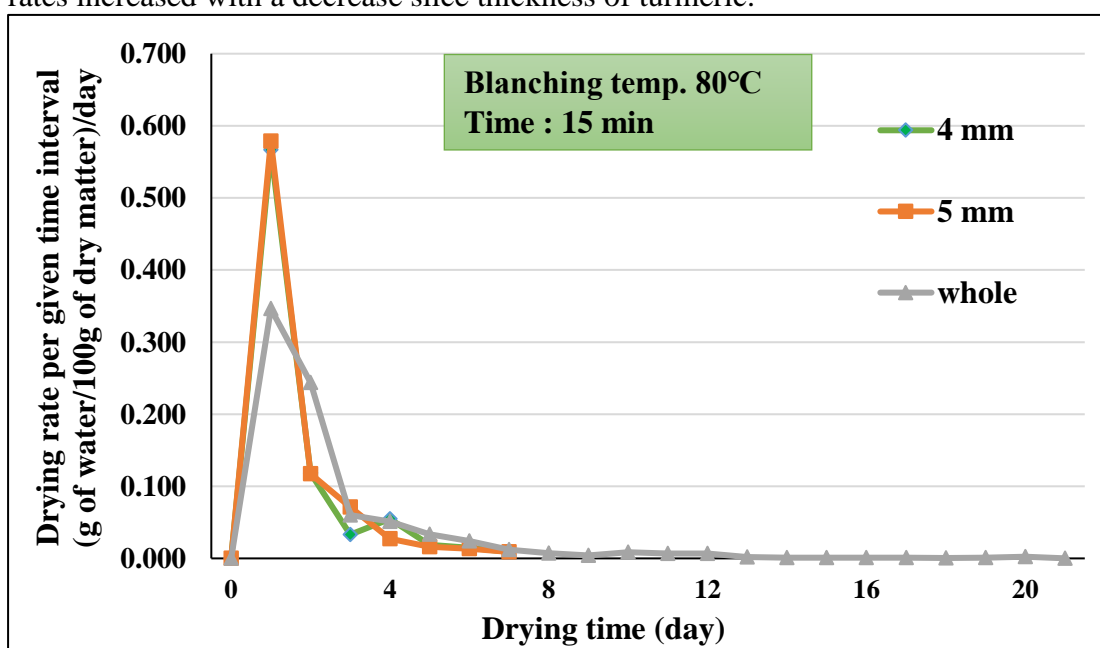


Fig.4.20 Effect in the drying rate with drying time of turmeric blanched at 80°C for 15 min using solar tunnel drying

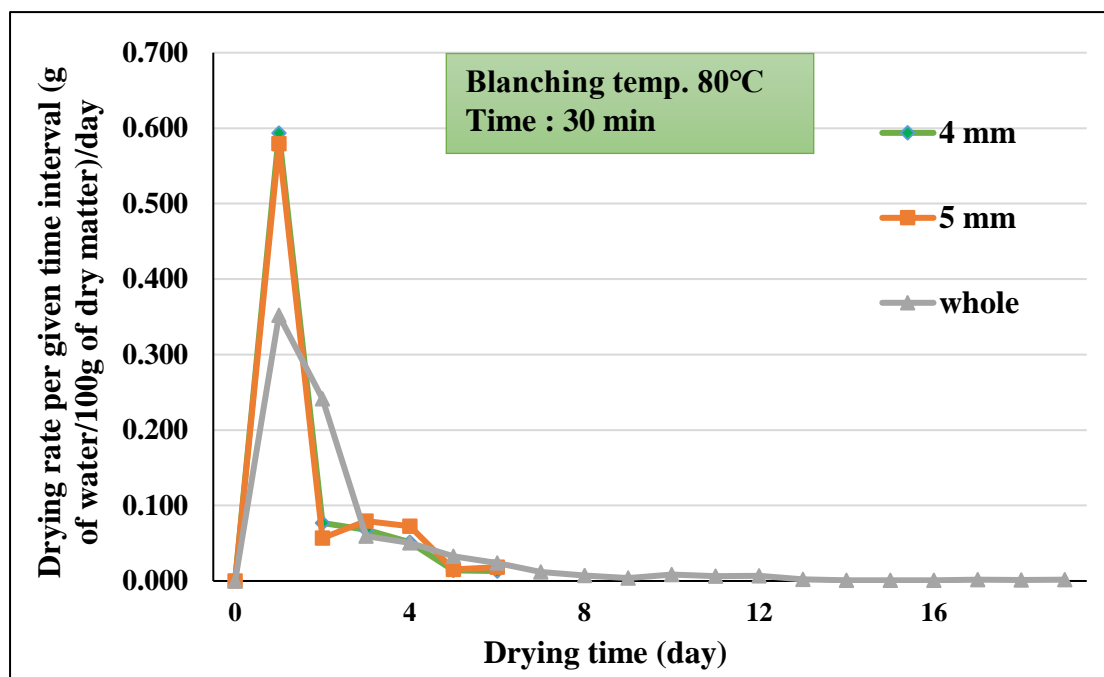


Fig.4.21 Effect in the drying rate with drying time of turmeric blanching at 80°C for 30 min using solar tunnel drying

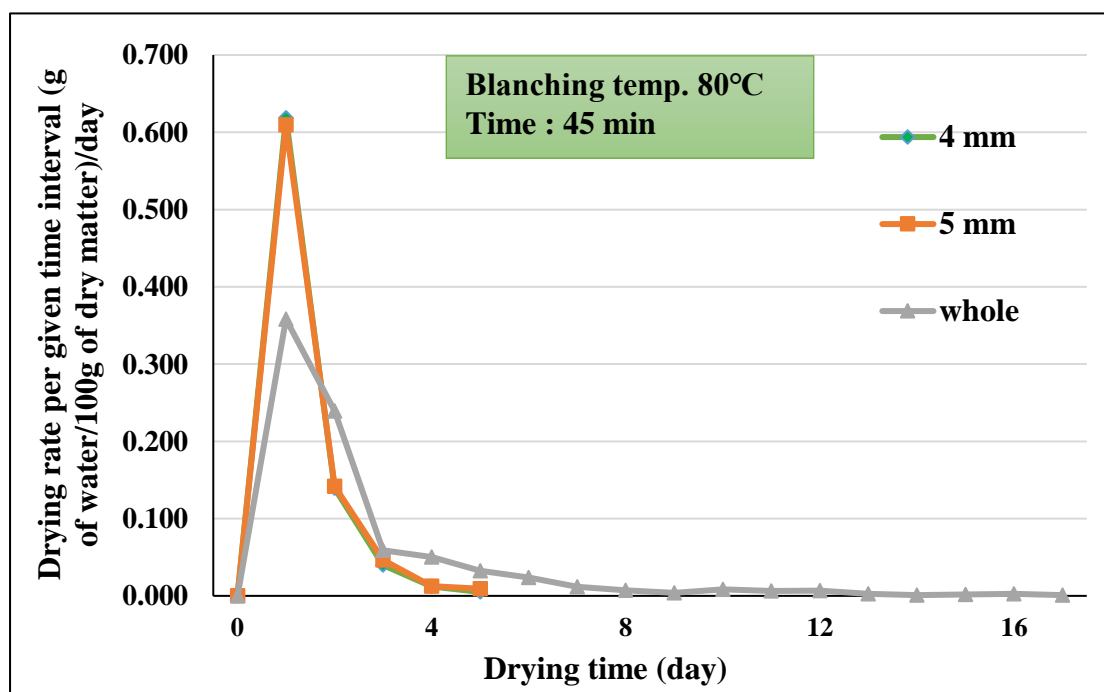


Fig. 4.22 Effect in the drying rate with drying time of turmeric blanching at 80°C for 45 min using solar tunnel drying

Standard practice of blanching was done on the samples before drying. This increases the drying rate as samples are partially cooked and some cells or tissues of rhizome might be disrupted or loosened (Bala 1998). As a result, moisture diffusion was higher and hence the drying rate was higher. The effect becomes more prominent with the increase of the temperature.

3) Moisture ratio (MR) of blanched sliced and whole turmeric vs. drying time

The moisture ratio of samples during solar tunnel drying of turmeric is given in APPENDIX-C3 as well a graphical representation.

This observation is evident from Fig. 4.23 to Fig. 4.25. It is notable that the lower moisture ratios were observed in the treatment B₂M₃S₁D₁ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-4 mm) and B₂M₃S₂D₁ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-5 mm) while the higher moisture ratios were observed in the treatment B₂M₁S₃D₁ (Blanching temperature-80°C, Blanching time-15 min, and Slice thickness-whole). While the moisture rate variations were almost similar for the B₂M₃S₁D₁ and B₂M₃S₂D₁ treatments, the B₂M₁S₃D₁ treatment showed the higher moisture ratios duration for the drying process.

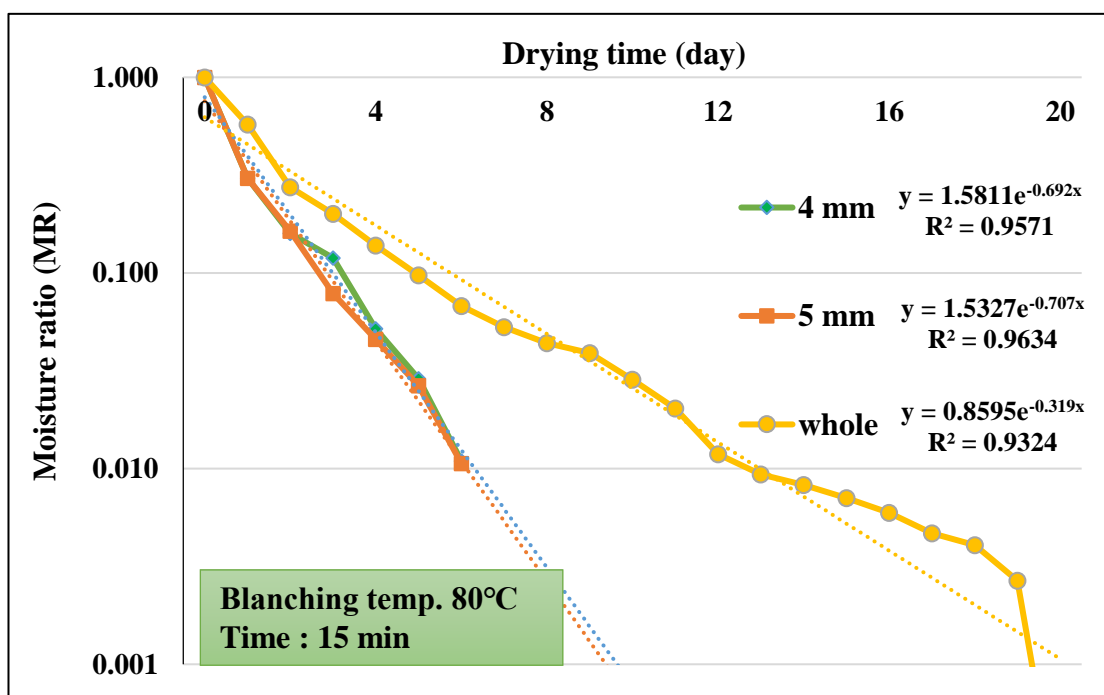


Fig. 4.23 Effect in the moisture ratio with drying time of turmeric blanched at 80°C for 15 min using solar tunnel drying

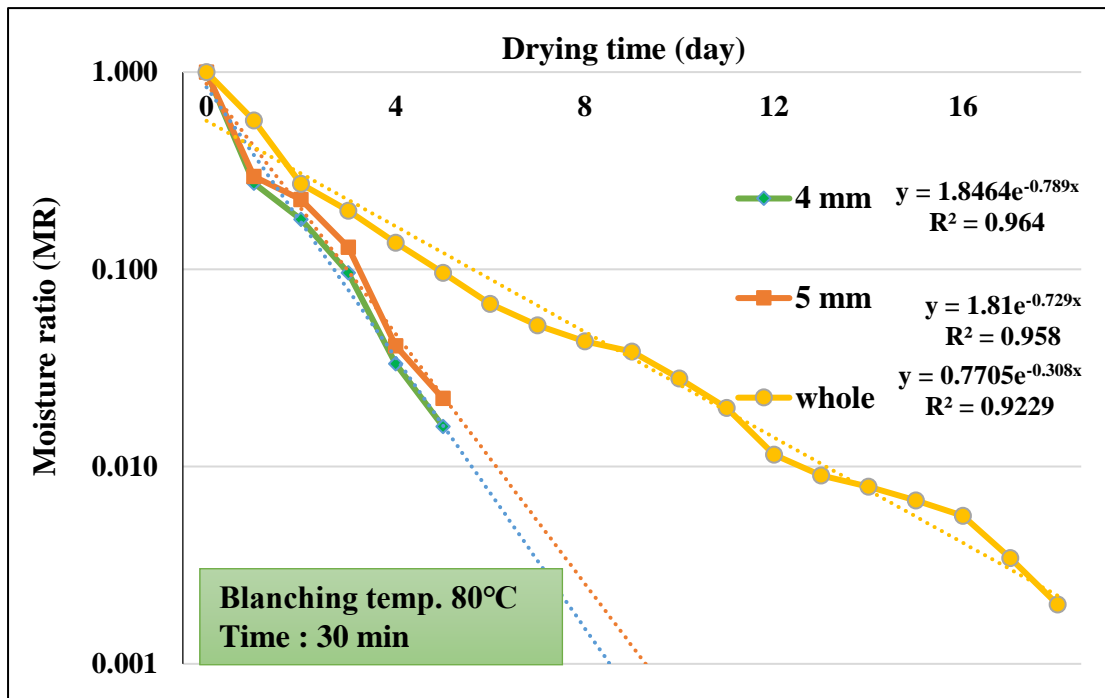


Fig. 4.24 Effect in the moisture ratio with drying time of turmeric blanching at 80°C for 30 min using solar tunnel drying

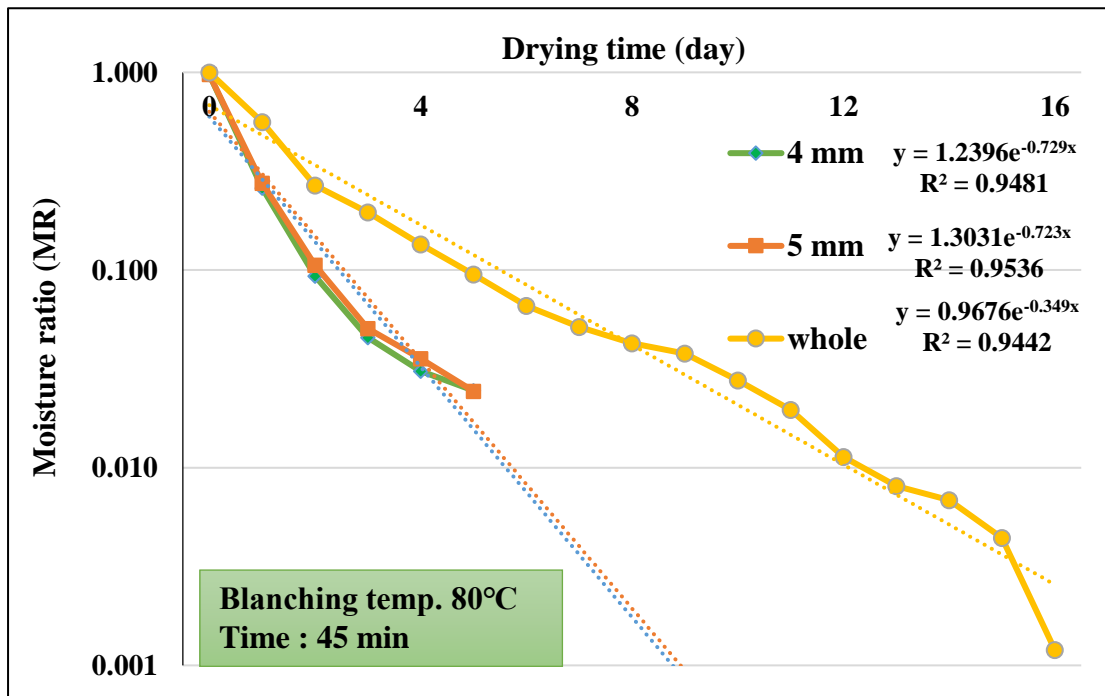


Fig. 4.25 Effect in the moisture ratio with drying time of turmeric blanching at 80°C for 45 min using solar tunnel drying

The moisture ratio of blanched turmeric slices and whole was decreased exponentially with the drying time. In the initial stage, the moisture ratio dropped faster and it slowed down in the later stages of drying irrespective of treatments (Velappan *et al.*, 1993).

The results indicate that the moisture ratios of whole rhizomes are influenced by the blanching time and temperature, with lower blanching temperatures and shorter blanching times resulting in higher moisture ratios. This was observed in turmeric samples with lower slice thickness and higher blanching temperatures showing lower moisture ratios.

4) Treatments of blanched sliced and whole turmeric vs. drying time

The drying time for the different samples of blanched turmeric slices and whole is given in APPENDIX-C1 and the comparative view of drying time for the different treatments is graphically presented in Fig. 4.26. The maximum drying time was recorded as 21 days in treatment B₂M₁S₃D₁ (Blanching temperature = 80°C, Blanching time = 15 min, and Slice thickness = whole). While, the minimum drying time was found 5 days in treatment B₂M₃S₁D₁ (Blanching temperature= 80°C, Blanching time=45 min, and Slice thickness = 4 mm) and B₂M₃S₂D₁ (5 mm).

It was observed that blanching time and temperature significantly affected the drying time. As the blanching time and temperature increased the drying time decreased (Jayashree and Zachariah 201).

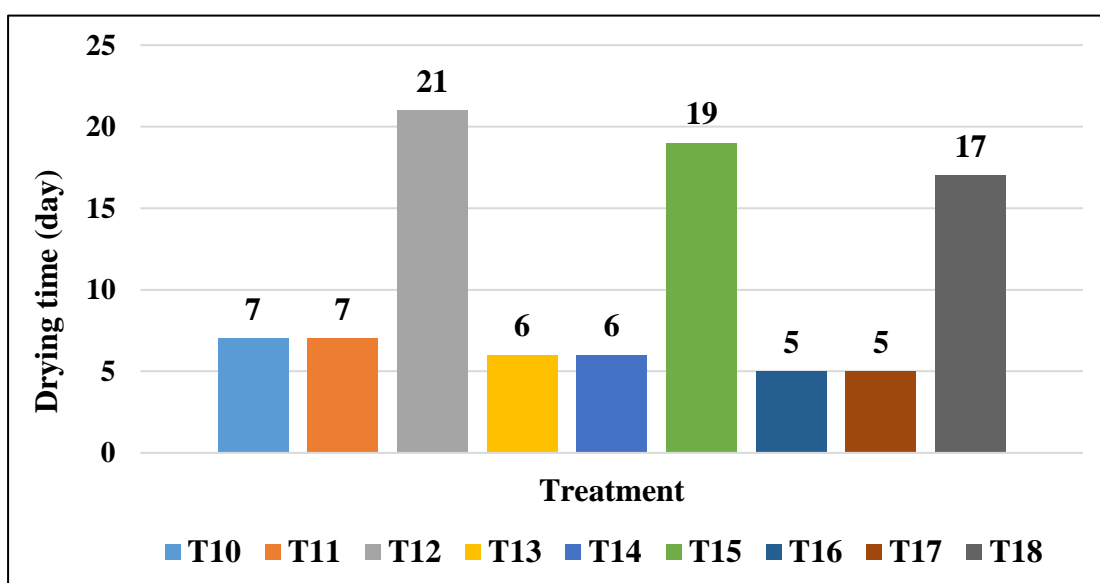


Fig. 4.26 Treatments with drying time during solar tunnel drying

4.7.1.3 Drying characteristics of blanched whole and sliced turmeric at 90°C

The details of treatment combinations are given in Table 3.2(a) of Chapter III.

1) Moisture content of blanched sliced and whole turmeric vs. drying time

The moisture content of samples during solar tunnel drying of turmeric is given in APPENDIX-D1 as well a graphical representation of moisture content with respect to drying time is illustrated in Fig. 4.27 to Fig. 4.29. The relationship between moisture content and drying time was determined to be non-linear, in the initial stage of drying showing a larger decrease in moisture compared to the later stages. Similar type of trends was also observed for other blanching treatment as shown in Fig. 4.27 to Fig. 4.29. It was observed that the moisture content reduction was relatively higher for treatment B₃M₃S₁D₁ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-4 mm) and B₃M₃S₂D₁ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-5 mm) in comparison to B₃M₁S₃D₁ (Blanching temperature-90°C, Blanching time-15 min, and Slice thickness-whole). While the drying time variations were almost similar for the B₃M₃S₁D₁ and B₃M₃S₂D₁ treatments, the B₃M₁S₃D₁ treatment showed the longest duration for the drying process.

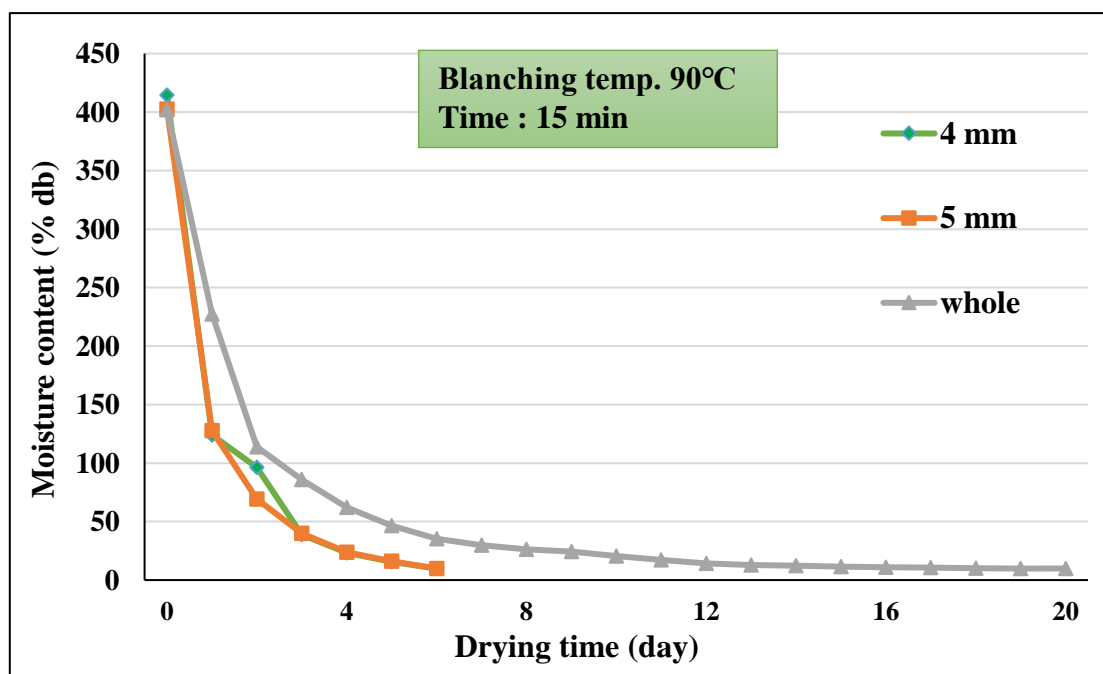


Fig.4.27 Effect in the moisture content with drying time of turmeric blanched at 90°C for 15 min using solar tunnel drying

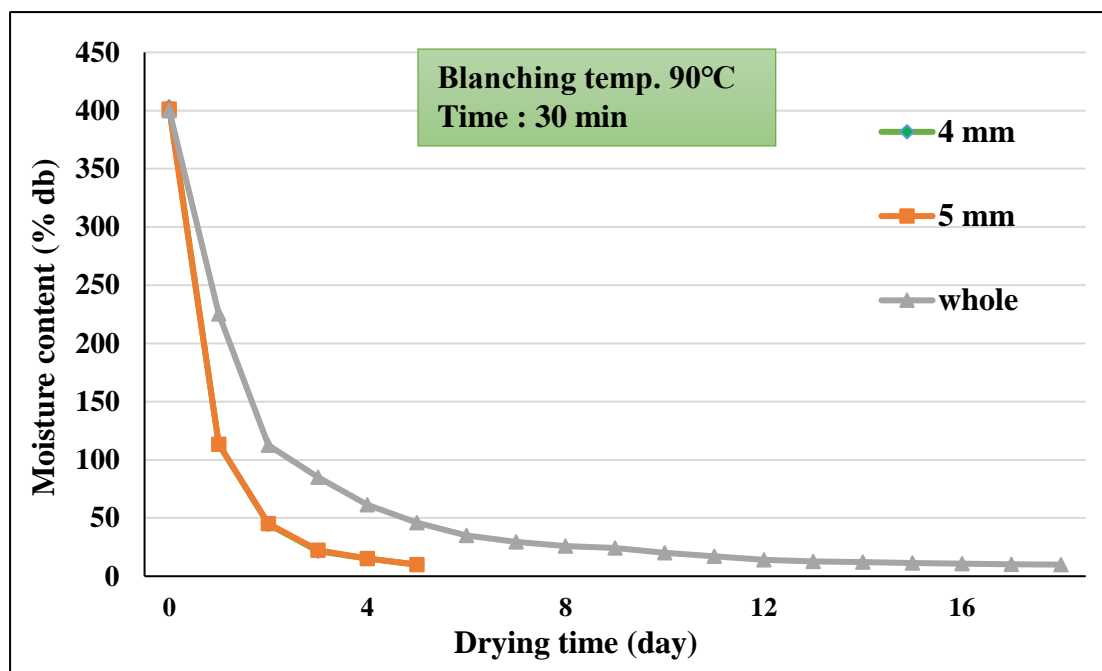


Fig.4.28 Effect in the moisture content with drying time of turmeric blanching at 90°C for 30 min using solar tunnel drying

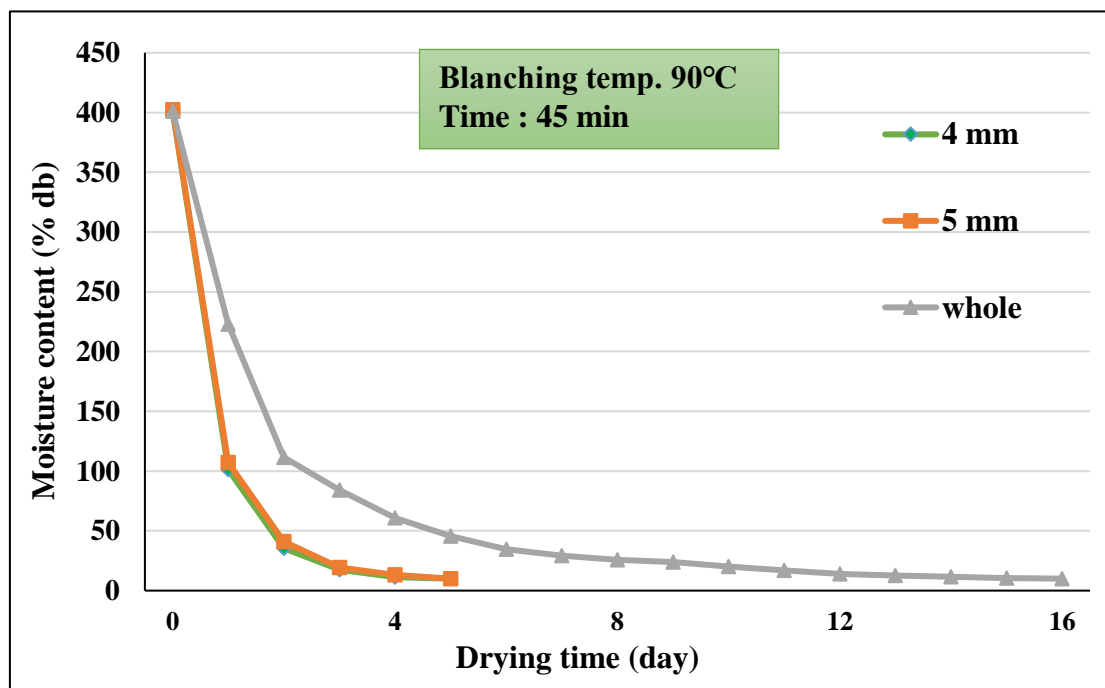


Fig.4.29 Effect in the moisture content with drying time of turmeric blanching at 80°C for 45 min using solar tunnel drying

It was observed that the turmeric blanched at 90⁰C for 45 min, rate of moisture removal was faster in 4 mm, 5 mm and whole turmeric resulted in lower drying time, i.e., 5 , 5 and 16 days, respectively. Followed by turmeric blanched at 90⁰C for 30 min and higher drying times at 90⁰C for 15 min treatments. This shows as the blanching time increased at constant blanching temperature (90⁰C), drying time decreased proportionately.

The turmeric in the solar tunnel dryer dried at a faster rate compared to open sun drying. The turmeric in the solar dryer dried at a faster rate mainly due to the higher temperature achieved in the dryer which causes higher diffusion of moisture from the interior to the surface of turmeric as compared to turmeric dried in ambient conditions (Gill *et al.*, 2021).

2) Drying rate of blanched sliced and whole turmeric vs. drying time

The drying rate of samples during solar tunnel drying of turmeric is given in APPENDIX-D2 as well a graphical representation of the drying rate with respect to drying time is illustrated in Fig. 4.30 to Fig. 4.32.

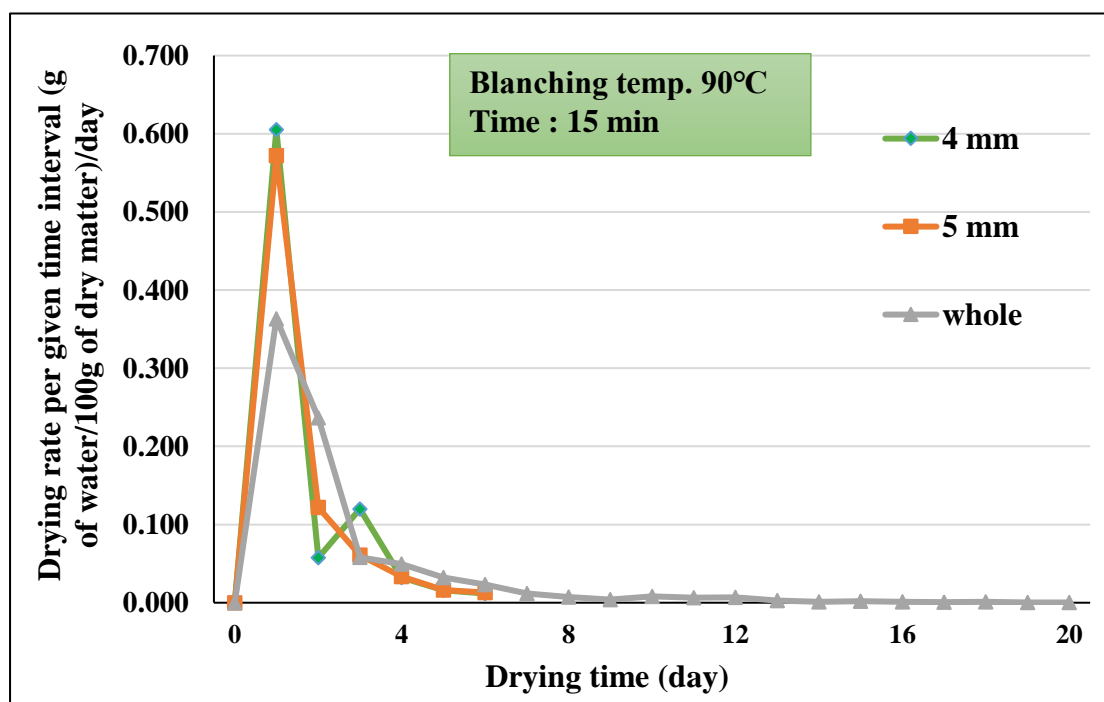


Fig.4.30 Effect in the drying rate with drying time of turmeric blanched at 90°C for 15 min using solar tunnel drying

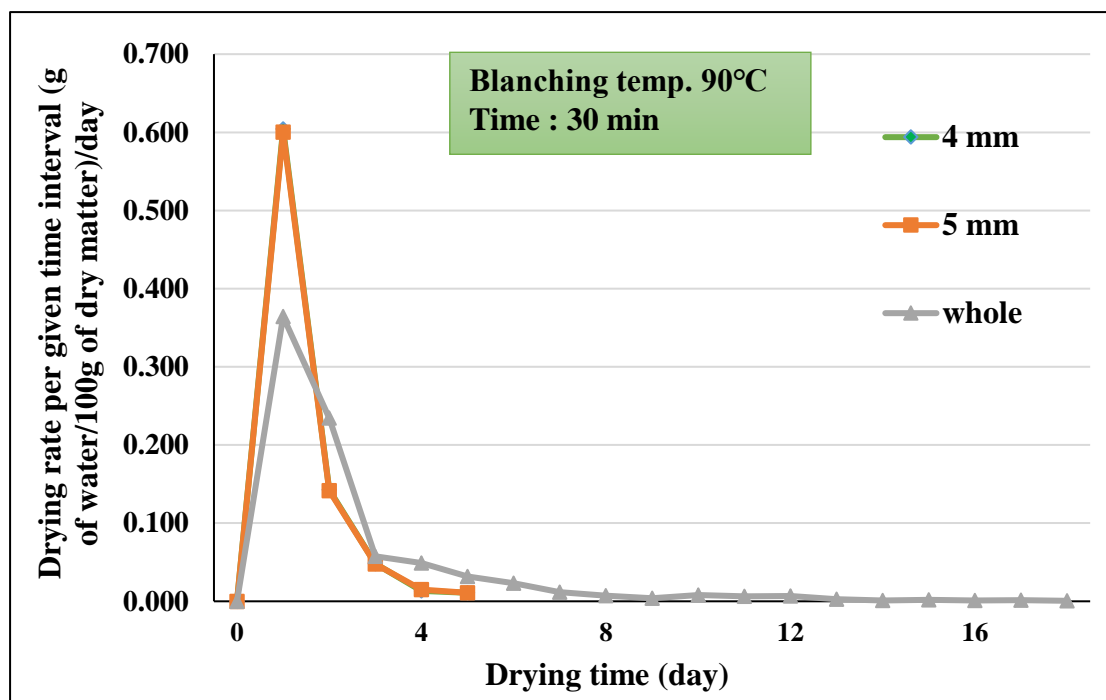


Fig.4.31 Effect in the drying rate with drying time of turmeric blanching at 90°C for 30 min using solar tunnel drying

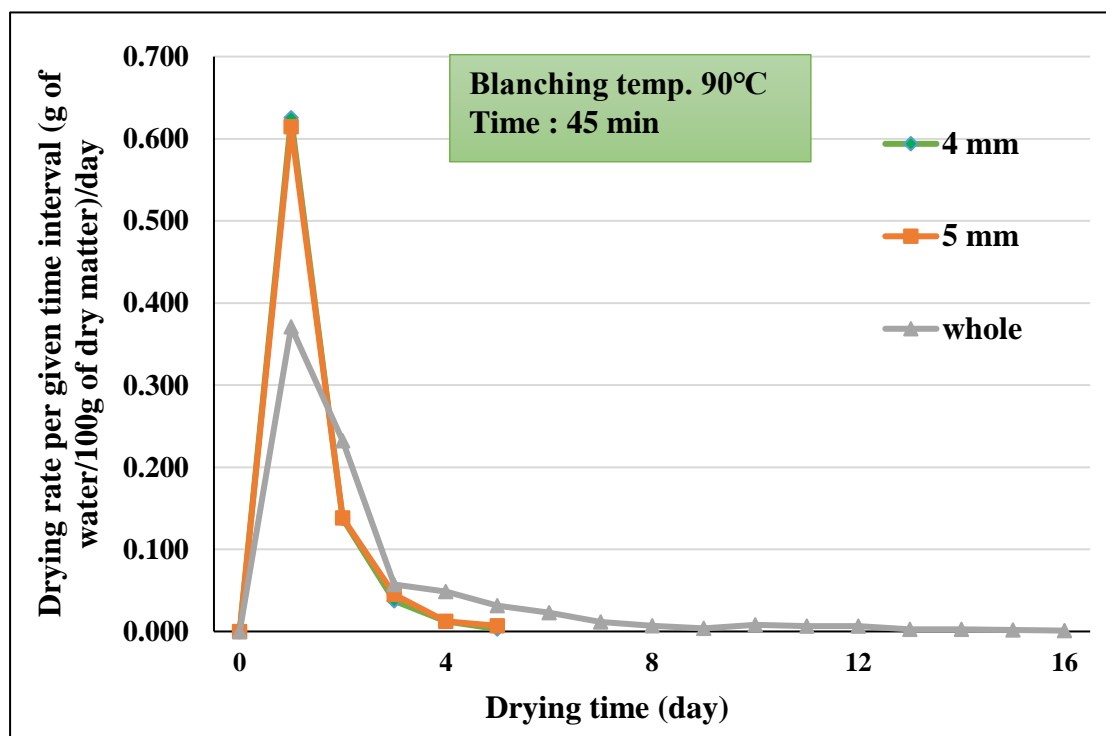


Fig.4.32 Effect in the drying rate with drying time of turmeric blanching at 90°C for 45 min using solar tunnel drying

The relationship between drying rate and drying time was determined to be non-linear, with the initial stage of drying showing a decrease in rates compared to the later stages of drying. Similar types of trends were also observed for other blanching treatments as shown in Fig. 4.30 to Fig. 4.32. It was observed that the drying rate increase was relatively higher for treatment B₃M₃S₁D₁ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-4 mm) and B₃M₃S₂D₁ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-5 mm) in comparison to B₃M₁S₃D₁ (Blanching temperature-90°C, Blanching time-15 min, and Slice thickness-whole). It was observed that drying rates increased with a decrease in slice thickness of turmeric.

Drying occurred in the falling rate period for both samples. It could be seen that the rate of drying was much faster in the case of sliced samples in comparison to whole samples up to the end of the initial 7 h of drying (Borah *et al.*, 2015).

3) Moisture ratio (MR) of blanched sliced and whole turmeric vs. drying time

The moisture ratio of samples during solar tunnel drying of turmeric is given in APPENDIX-D3.

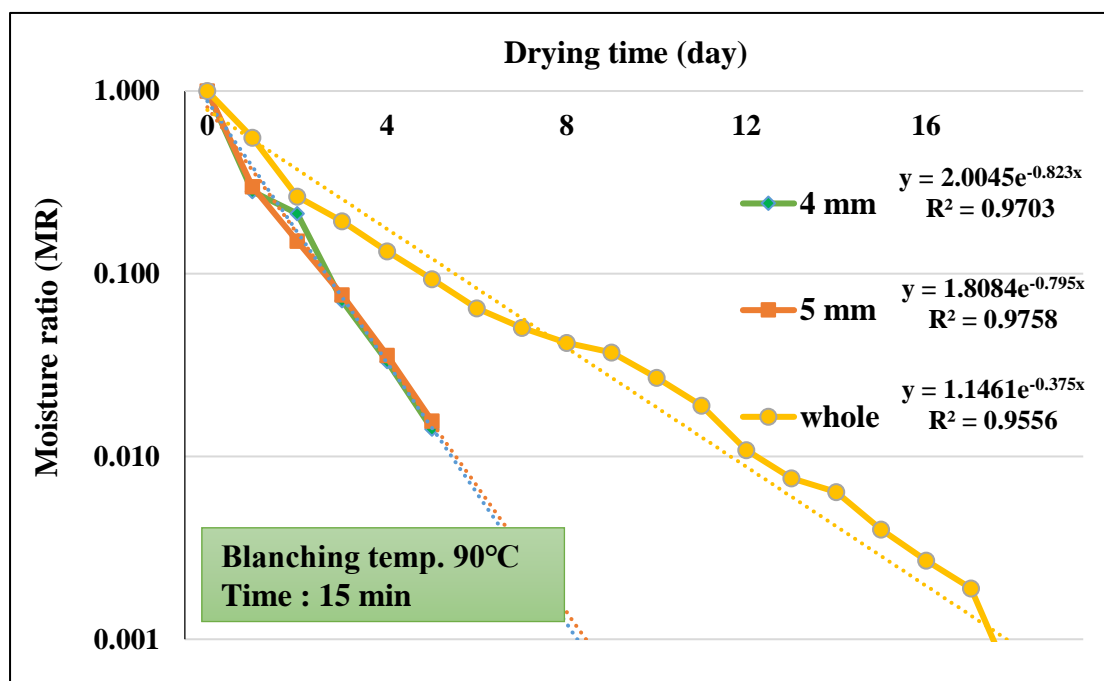


Fig. 4.33 Effect in the moisture ratio with drying time of turmeric blanched at 90°C for 15 min using solar tunnel drying

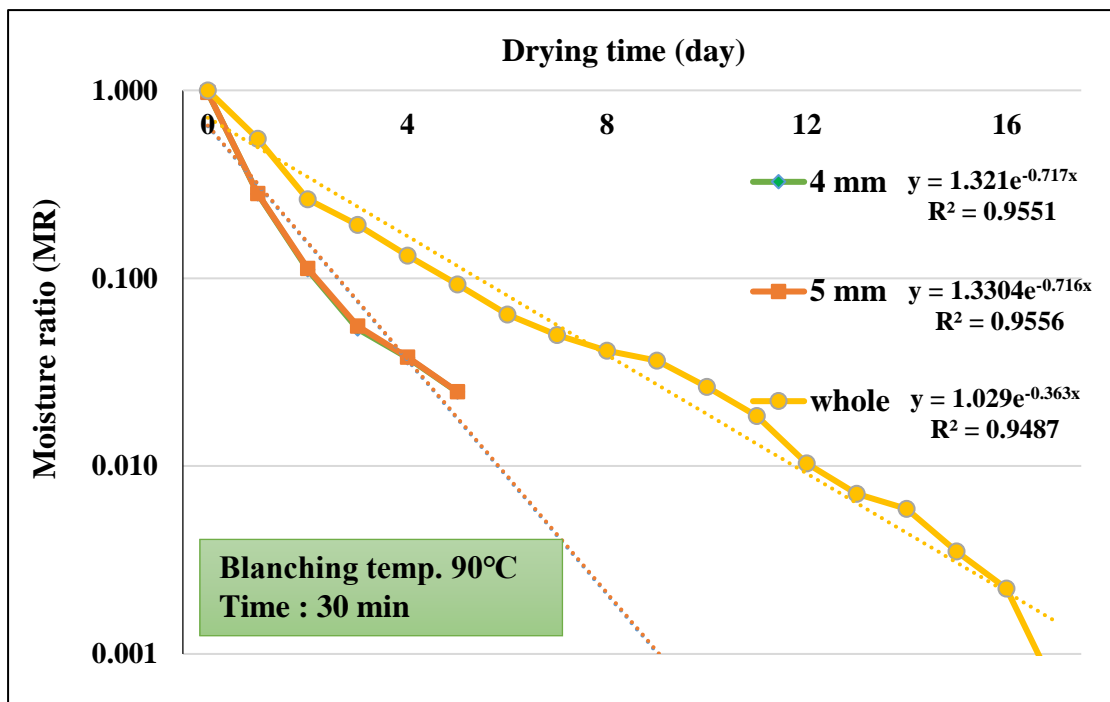


Fig. 4.34 Effect in the moisture ratio with drying time of turmeric blanching at 90°C for 30 min using solar tunnel drying

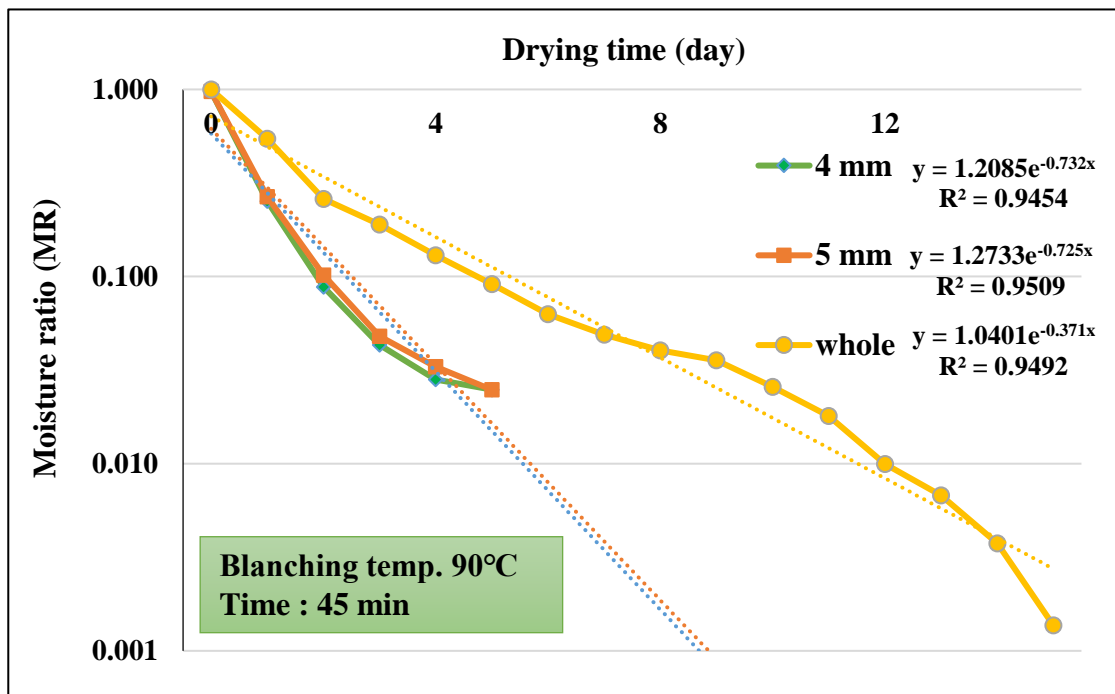


Fig. 4.35 Effect in the moisture ratio with drying time of turmeric blanching at 90°C for 45 min using solar tunnel drying

The moisture ratio of blanched turmeric slices and whole was decreased exponentially with the drying time. In the initial stage, the moisture ratio dropped faster and it slowed down in the later stages of drying irrespective of treatments (Velappan *et al.*, 1993).

This observation is evident from Fig. 4.33 to Fig. 4.35. Notably, the lower moisture ratios were observed in the treatment B₃M₃S₁D₁ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-4 mm) and B₃M₃S₂D₁ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-5 mm) while the higher moisture ratios were observed in the treatment B₃M₁S₃D₁ (Blanching temperature-90°C, Blanching time-15 min, and Slice thickness-whole). While the moisture rate variations were almost similar for the B₃M₃S₁D₁ and B₃M₃S₂D₁ treatments, the B₃M₁S₃D₁ treatment showed the higher moisture ratios duration for the drying process. The results indicate that the moisture ratios of whole rhizomes are influenced by the blanching time and temperature, with lower blanching temperatures and shorter blanching times resulting in higher moisture ratios. This was observed in turmeric samples with lower slice thickness and higher blanching temperatures showing lower moisture ratios.

Effect in drying constant of dried turmeric

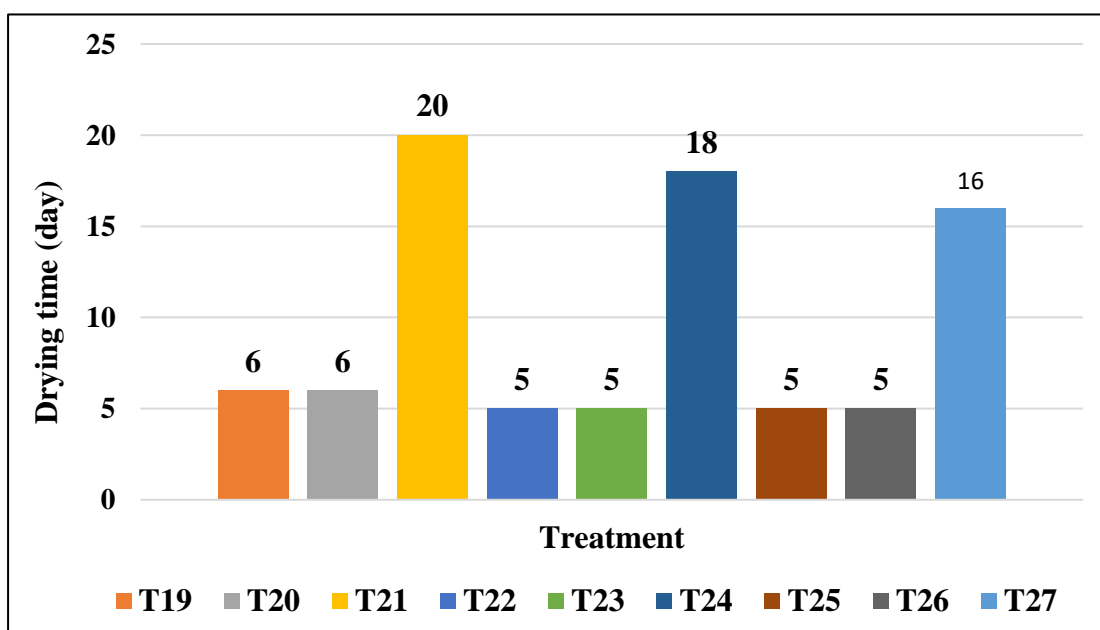
The values of the drying constant are an indication of the efficiency of the drying process. Table: A.A revealed that the values of drying constant for 4 mm thicknesses were higher in all the treatments as compared to 5 mm sliced turmeric and whole rhizomes., i.e., as the thickness increases value of the drying constant decreases. Furthermore, blanching temperature and blanching time increase values of drying constant increases proportionately. In addition to these, the highest values of drying constants, viz., 0.825d⁻¹, 0.717 d⁻¹ and 0.732 d⁻¹ for 4 mm slices thickness at 90⁰ C & 15 min, 90⁰ C & 30 min and 90⁰ C & 45 min, respectively. Followed by 5 mm thickness and lowest values of drying constants viz., 0.375 d⁻¹, 0.363 d⁻¹ and 0.371 d⁻¹ were obtained in all the treatments for whole turmeric rhizomes dried at 90⁰ C & 15 min, 90⁰ C & 30 min and 90⁰ C & 45 min, respectively. However, very little variation in values of drying constant was observed in turmeric slices dried at 4 mm and 5 mm.

Table 4.5 Effect in drying constant of solar tunnel dried turmeric

| Sr. No. | Treatments | 4 mm | 5 mm | whole |
|---------|-------------------------------|-------|-------|-------|
| 1 | B ₁ M ₁ | 0.721 | 0.679 | 0.303 |
| 2 | B ₁ M ₂ | 0.709 | 0.639 | 0.280 |
| 3 | B ₁ M ₃ | 0.748 | 0.746 | 0.447 |
| 4 | B ₂ M ₁ | 0.692 | 0.707 | 0.319 |
| 5 | B ₂ M ₂ | 0.789 | 0.729 | 0.308 |
| 6 | B ₂ M ₃ | 0.729 | 0.723 | 0.349 |
| 7 | B ₃ M ₁ | 0.823 | 0.795 | 0.375 |
| 8 | B ₃ M ₂ | 0.717 | 0.716 | 0.363 |
| 9 | B ₃ M ₃ | 0.732 | 0.725 | 0.371 |

4) Treatments of blanched sliced and whole turmeric vs. drying time

The drying time for the different samples of blanched turmeric slices and the whole is given in the APPENDIX-D1 and the comparative view of drying time for the different treatments is graphically presented in Fig. 4.36. The maximum drying time was recorded as 19 days in treatment B₃M₁S₃D₁ (Blanching temperature = 90°C, Blanching time = 15 min, and Slice thickness = whole). While, the minimum drying time was found 5 days in treatment B₃M₃S₁D₁ (Blanching temperature = 90°C, Blanching time = 45 min, and Slice thickness = 4 mm) and B₃M₃S₂D₁ (Blanching temperature = 90°C, Blanching time = 45 min, and Slice thickness = 5 mm).

**Fig. 4.36 Treatments with drying time during solar tunnel drying**

It was observed that blanching time and temperature significantly affected the drying time. As the blanching time and temperature increased the drying time decreased. Blanching for a longer duration softens the tissues and enhanced the removal of water at a faster rate thus reduced the drying time (Jayashree and Zachariah 2016).

4.7.2 Experiment 2: Drying of turmeric rhizomes by sun drying

4.7.2.1 Drying characteristics of blanched whole and sliced turmeric at 70°C

The details of treatment combinations are given in Table 3.2(b) of Chapter III.

1) Moisture content of blanched sliced and whole turmeric vs. drying time

Moisture content of samples during sun drying of turmeric is given in APPENDIX-E1 as well as a graphical representation of moisture content with respect to drying time is illustrated in Fig. 4.37 to Fig. 4.39.

The relationship between moisture content and drying time was determined to be non-linear, in the initial stage of drying showing a larger decrease in moisture compared to the later stages. Similar type of trends was also observed for other blanching treatment as shown in Fig. 4.37 to Fig. 4.39. It was observed that the moisture content reduction was relatively higher for treatment B₁M₃S₁D₂ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-4 mm) and B₁M₃S₂D₂ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-5 mm) in comparison to B₁M₁S₃D₂ (Blanching temperature-70°C, Blanching time-15 min, and Slice thickness-whole). While the drying time variations were almost similar for the B₁M₃S₁D₂ and B₁M₃S₂D₂ treatments, the B₁M₁S₃D₂ treatment showed the longest duration for the drying process.

It was observed that the turmeric blanched at 70°C for 45 min, the rate of moisture removal was faster at 4 mm, 5 mm and whole turmeric resulted in lower drying time, i.e., 7, 7 and 37 days, respectively. Followed by turmeric blanched at 70°C for 30 min and higher drying times at 70°C for 15 min treatments. This shows as the blanching time increased at constant blanching temperature (70°C), drying time decreased proportionately.

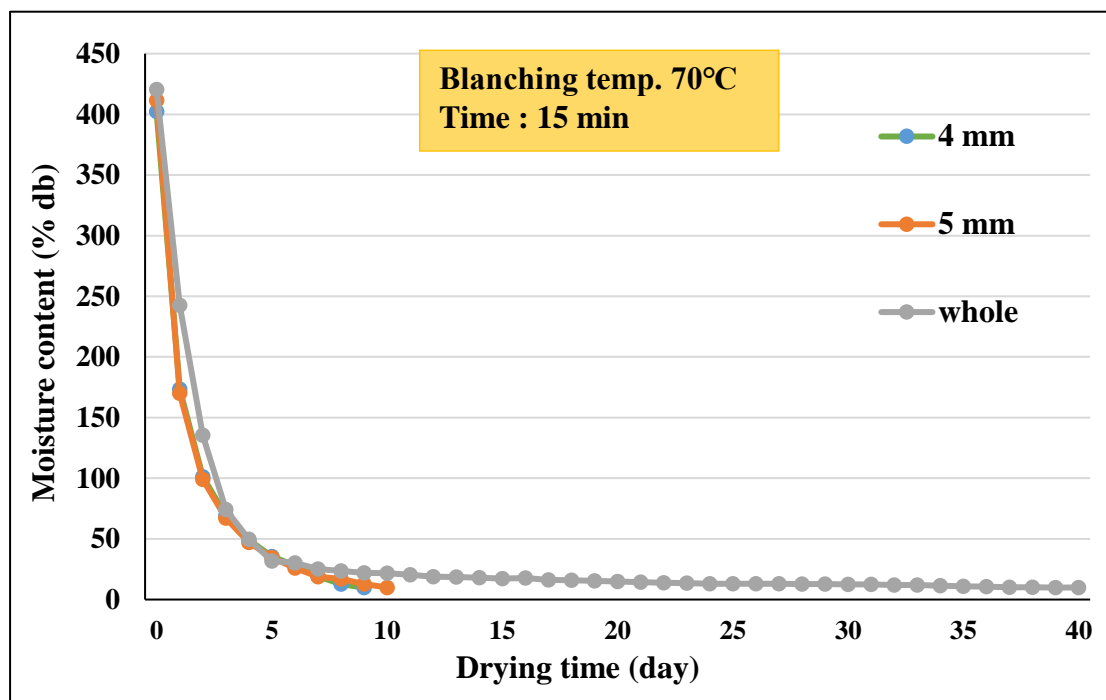


Fig.4.37 Effect in the moisture content with drying time of turmeric blanching at 70°C for 15 min using sun drying

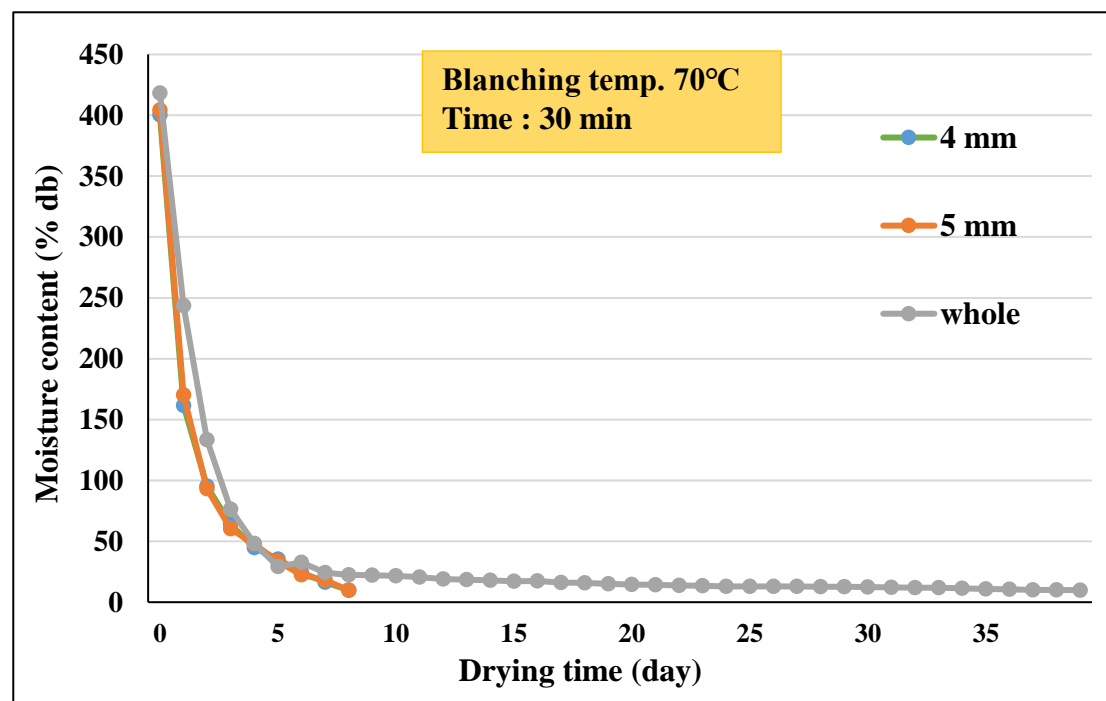


Fig. 4.38 Effect in the moisture content with drying time of turmeric blanching at 70°C for 30 min using sun drying

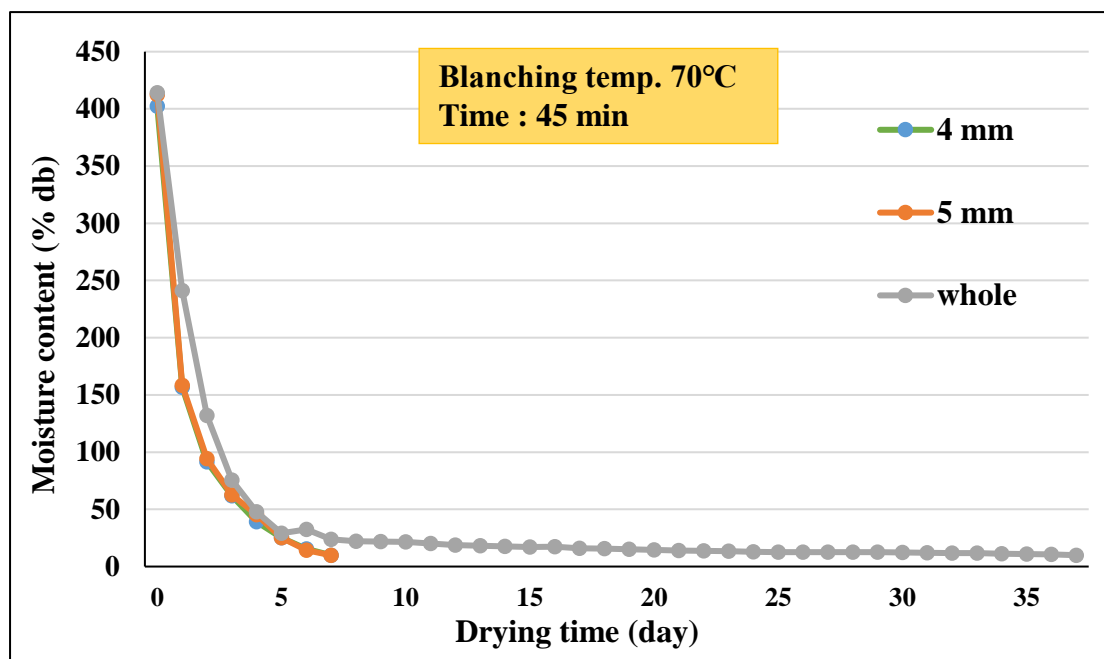


Fig. 4.39 Effect in the moisture content with drying time of turmeric blanching at 70°C for 45 min using sun drying

The turmeric in the solar tunnel dryer dried at a faster rate as compared to open sun drying. The turmeric in solar dryer dried at a faster rate mainly due to the higher temperature in the dryer, which causes higher diffusion of moisture from the interior to the surface of turmeric as compared to turmeric dried in ambient conditions (Gill *et al.*, 2021). It was observed that the lowest drying time of 16 days was obtained in STD of whole blanching 90°C & 45 minutes, whereas the highest drying time of 34 days was obtained in the SD method at the same conditions.

2) Drying rate of blanching sliced and whole turmeric vs. drying time

The drying rate of samples during sun drying of turmeric is given in APPENDIX-E2 as well as a graphical representation of the drying rate with respect to drying time is illustrated in Fig. 4.40 to Fig. 4.42.

The drying rate was higher during the initial period but as the drying progressed, the drying rate decreased gradually. This is due to more evaporation of moisture from the surface and later, the rate of moisture removal decreases mainly due to diffusion of moisture from the interior to the surface of turmeric. The faster drying of hydrothermally pretreated turmeric was because pores open up during the boiling of turmeric allowing faster flow of moisture to the surface (Velappan *et al.*, 1993).

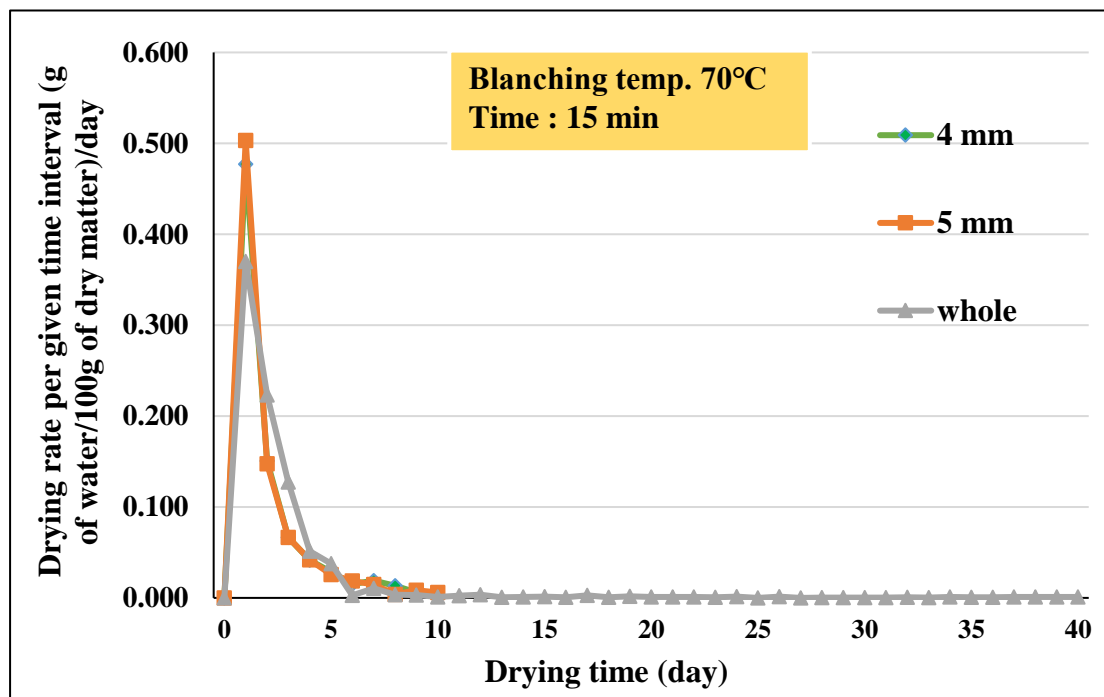


Fig.4.40 Effect in the drying rate with drying time of turmeric blanching at 70°C for 15 min using sun drying

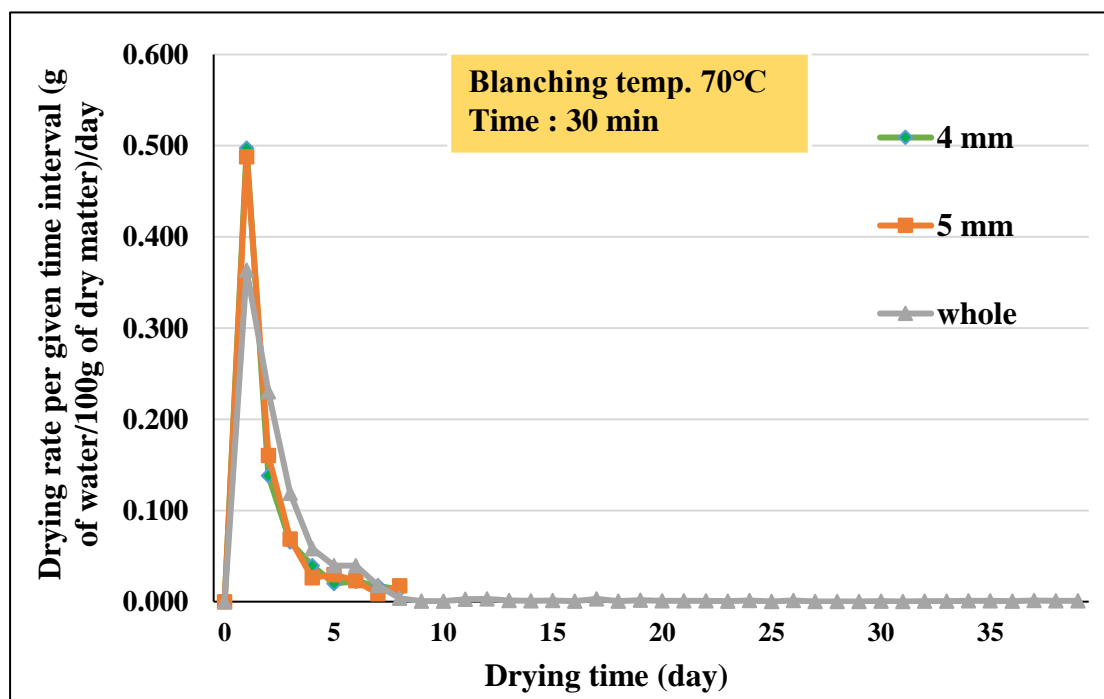


Fig.4.41 Effect in the drying rate with drying time of turmeric blanching at 70°C for 30 min using sun drying

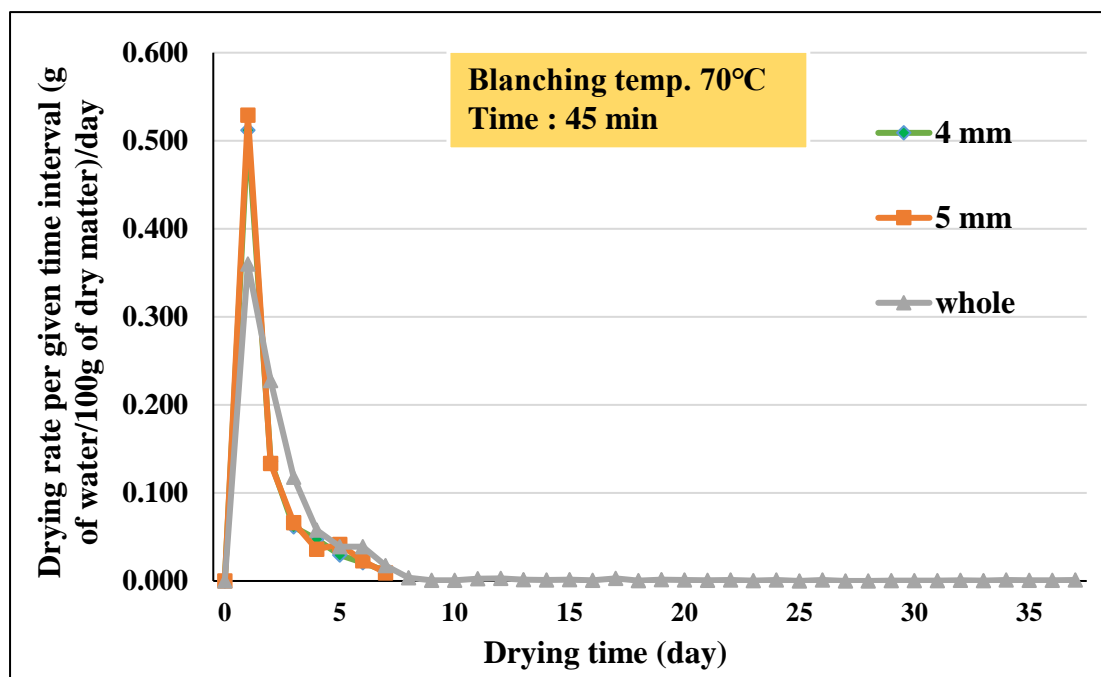


Fig.4.42 Effect in the drying rate with drying time of turmeric blanched at 70°C for 45 min using sun drying

The relationship between drying rate and drying time was determined to be non-linear, with the initial stage of drying showing a decrease in rates compared to the later stages of drying. Similar types of trends were also observed for other blanching treatments as shown in Fig. 4.40 to Fig. 4.42. It was observed that the drying rate increase was relatively higher for treatment $B_1M_3S_2D_2$ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-5 mm) and $B_1M_3S_1D_2$ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-4 mm) in comparison to $B_1M_3S_3D_2$ (Blanching temperature-70°C, Blanching time-15 min, and Slice thickness-whole). It was observed that drying rates increased with a decrease in slice thickness of turmeric.

3) Moisture ratio (MR) of blanched sliced and whole turmeric vs. drying time

The moisture ratio of samples during solar tunnel drying of turmeric is given in APPENDIX-E3 as well a graphical representation of moisture ratio (MR) with respect to drying time is illustrated in Fig. 4.43 to Fig. 4.45.

The moisture ratio of blanched turmeric slices and whole was decreased exponentially with the drying time. In the initial stage, the moisture ratio dropped faster

and it slowed down in the later stages of drying irrespective of treatments (Velappan *et al.*, 1993).

This observation is evident from Fig. 4.43 to Fig. 4.45. Notably, the lower moisture ratios were observed in the treatment B₁M₃S₁D₂ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-4 mm) and B₁M₃S₂D₂ (i.e., Blanching temperature-70°C, Blanching time-45 min, and Slice thickness-5 mm) while the higher moisture ratios were observed in the treatment B₁M₁S₃D₂ (Blanching temperature-70°C, Blanching time-15 min, and Slice thickness-whole). While the moisture rate variations were almost similar for the B₁M₃S₁D₂ and B₁M₃S₂D₂ treatments, the B₁M₁S₃D₂ treatment showed the higher moisture ratios duration for the drying process. The results indicate that the moisture ratios of whole rhizomes are influenced by the blanching time and temperature, with lower blanching temperatures and shorter blanching times resulting in higher moisture ratios. This was observed in turmeric samples with lower slice thickness and higher blanching temperatures showing lower moisture ratios.

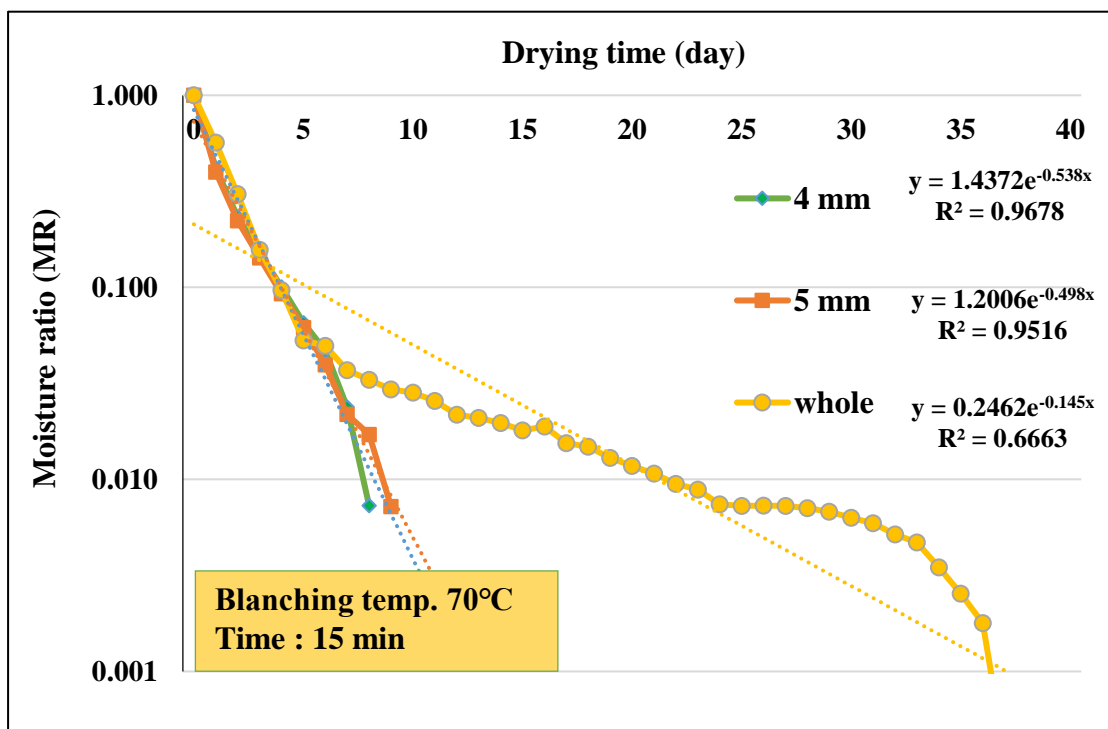


Fig. 4.43 Effect in the moisture ratio with drying time of turmeric blanching at 70°C for 15 min using sun drying

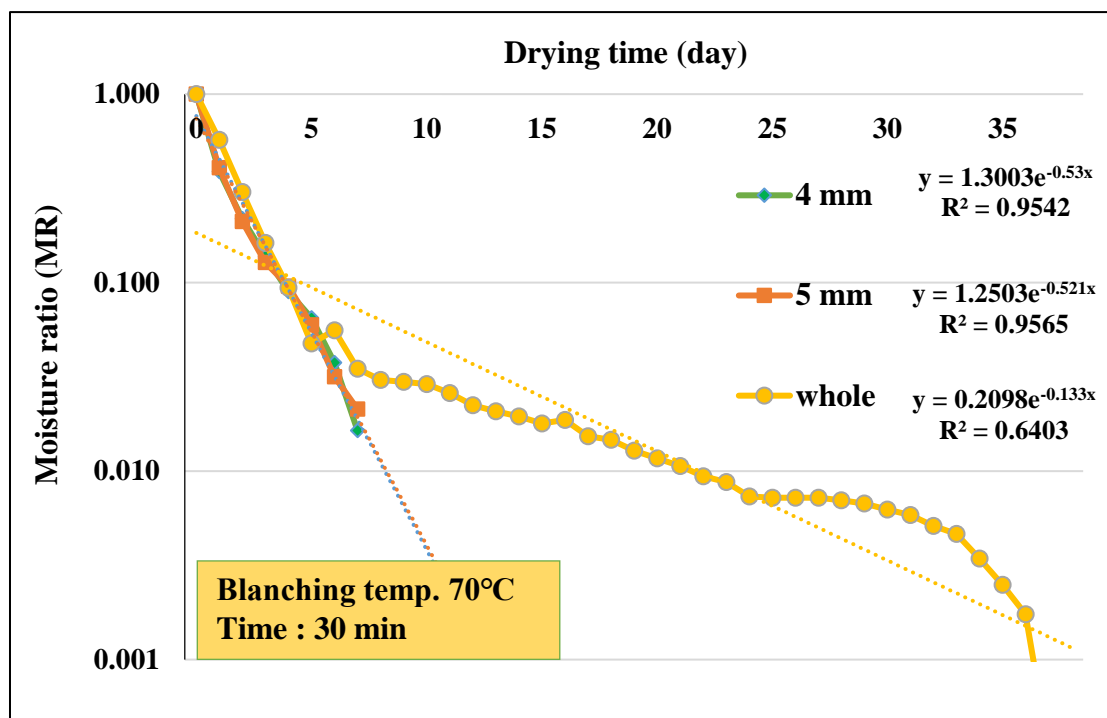


Fig. 4.44 Effect in the moisture ratio with drying time of turmeric blanching at 70°C for 30 min using sun drying

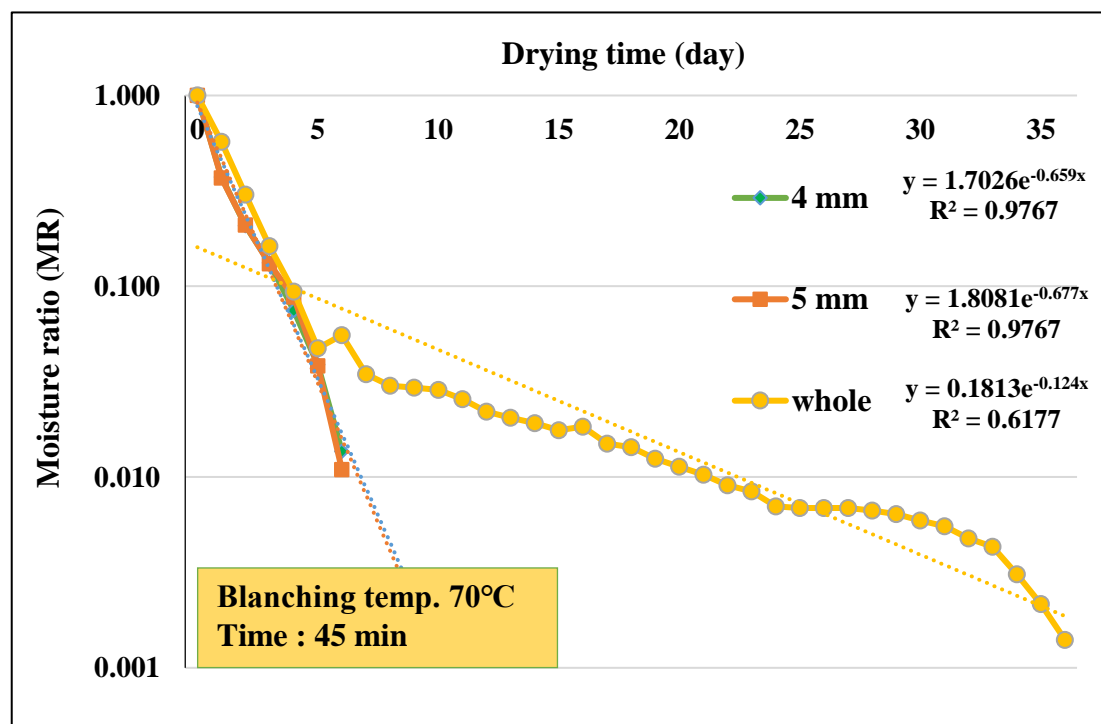


Fig. 4.45 Effect in the moisture ratio with drying time of turmeric blanching at 70°C for 45 min using sun drying

4) Treatments of blanched sliced and whole turmeric vs. drying time

The drying time for the different samples of blanched turmeric slices and whole is given in APPENDIX-E1 and the comparative view of drying time for the different treatments is graphically presented in Fig. 4.46. The maximum drying time was recorded as 40 days in treatment B₁M₁S₃D₂ (Blanching temperature = 70°C, Blanching time = 15 min, and Slice thickness = whole). While, the minimum drying time was found 7 days in treatment B₁M₃S₁D₂ (Blanching temperature = 70°C, Blanching time = 45 min, and Slice thickness = 4 mm) and B₁M₃S₂D₂ (Blanching temperature = 70°C, Blanching time = 45 min, and Slice thickness = 5 mm).

It was observed that blanching time and temperature significantly affected the drying time. As the blanching time and temperature increased the drying time was decreased. (Jayashree and Zachariah 2018).

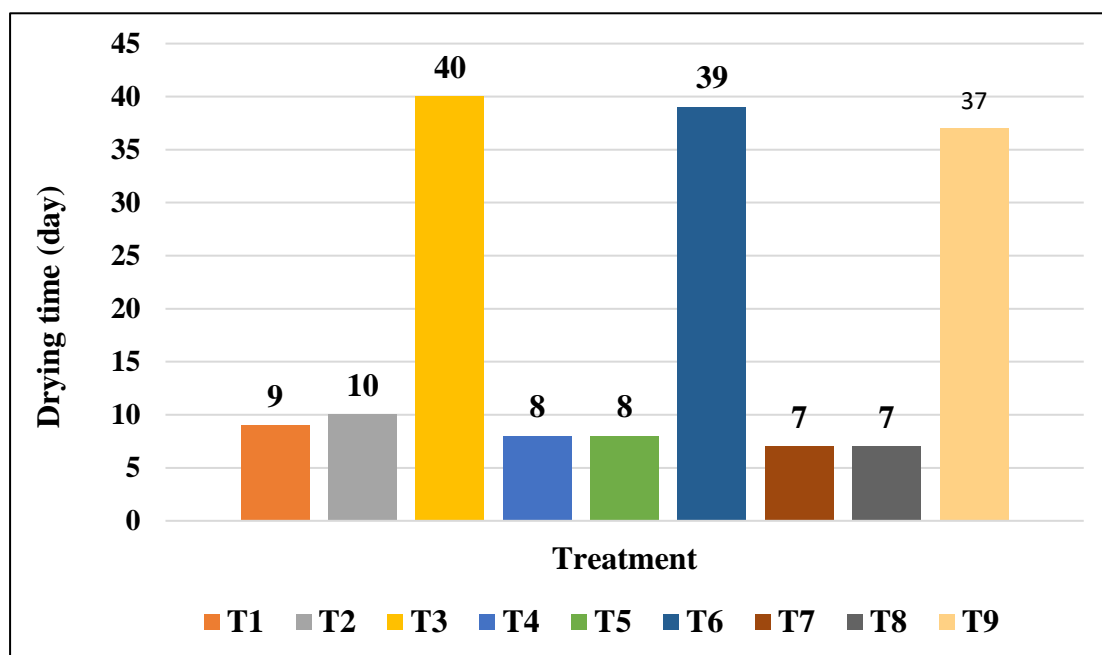


Fig. 4.46 Treatments with drying time during sun drying

4.7.2.2 Drying characteristics of blanched whole and sliced turmeric at 80°C

The details of treatment combinations are given in Table 3.2(b) of Chapter III.

1) Moisture content of blanched sliced and whole turmeric vs. drying time

The moisture content of samples during the sun drying of turmeric is given in APPENDIX-F1 as well a graphical representation of moisture content with respect to drying time is illustrated in Fig. 4.47 to Fig. 4.49.

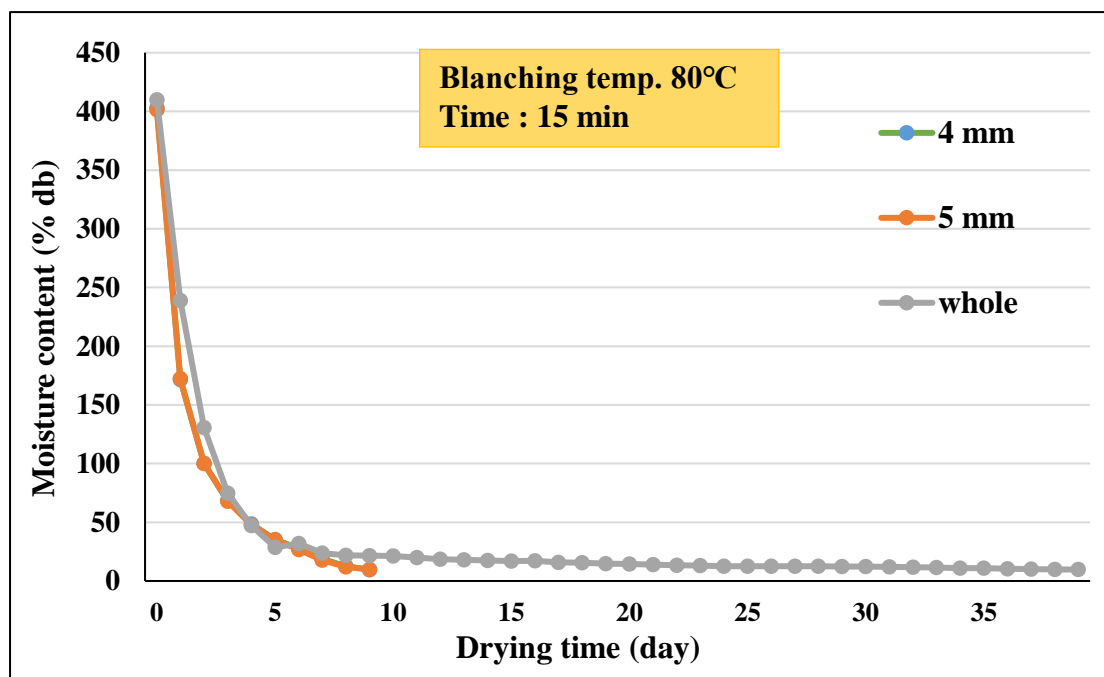


Fig. 4.47 Effect in the moisture content with drying time of turmeric blanching at 80°C for 15 min using sun drying

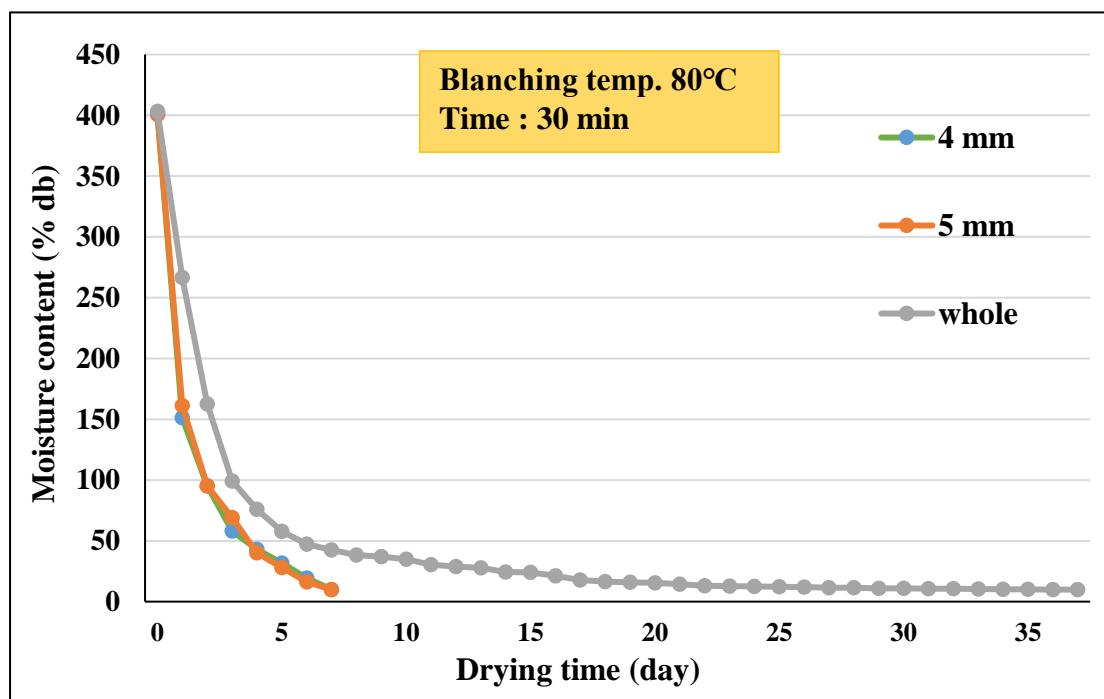


Fig. 4.48 Effect in the moisture content with drying time of turmeric blanching at 80°C for 30 min using sun drying

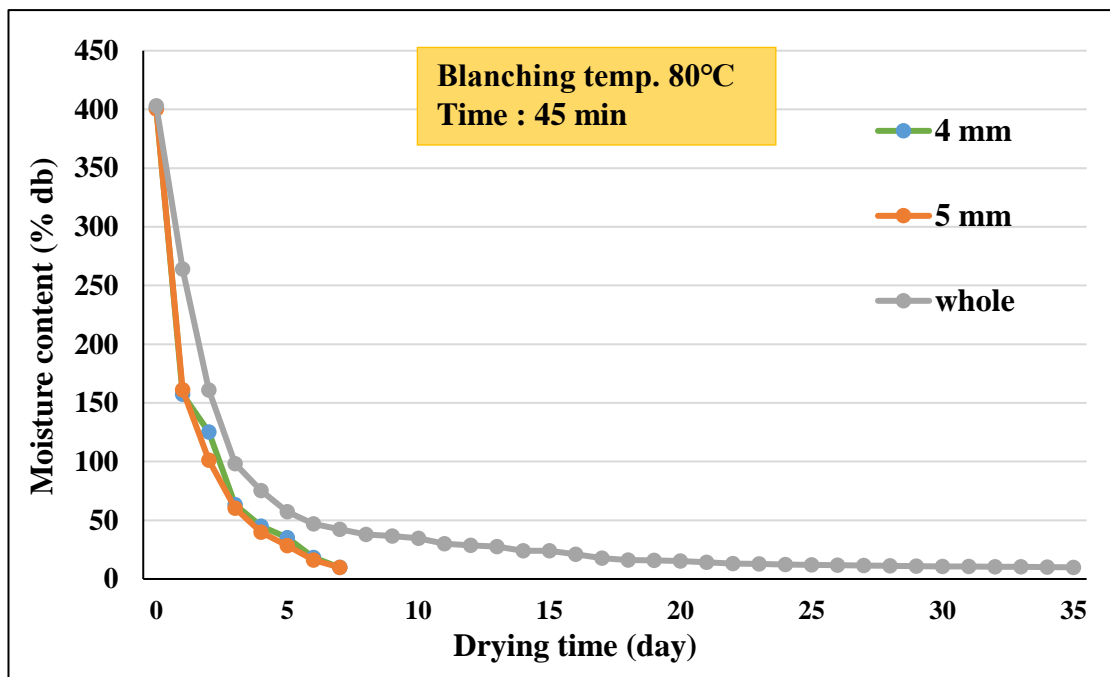


Fig. 4.49 Effect in the moisture content with drying time of turmeric blanching at 80°C for 45 min using sun drying

The relationship between moisture content and drying time was determined to be non-linear, in the initial stage of drying showing a larger decrease in moisture compared to the later stages. Similar type of trends was also observed for other blanching treatment as shown in Fig. 4.47 to Fig. 4.49. It was observed that the moisture content reduction was relatively higher for treatment B₂M₃S₁D₂ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-4 mm), B₂M₃S₂D₂ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-5 mm), in comparison to B₂M₁S₃D₂ (Blanching temperature-80°C, Blanching time-15 min, and Slice thickness-whole). While the drying time variations were almost similar for the B₂M₃S₁D₂ and B₂M₃S₂D₂ treatments, the B₂M₁S₃D₂ treatment showed the longest duration for the drying process.

It was observed that the turmeric blanching at 80°C for 45 min, the rate of moisture removal was faster at 4 mm, 5 mm and whole turmeric resulted in lower drying time, i.e., 7, 7 and 35 days, respectively. Followed by turmeric blanching at 80°C for 30 min and higher drying times at 80°C for 15 min treatments. This shows as the blanching time increased at constant blanching temperature (80°C), drying time decreased proportionately.

The turmeric in the solar tunnel dryer dried at a faster rate compared to open sun drying. (Gill *et al.*, 2021).

2) Drying rate of blanched sliced and whole turmeric vs. drying time

The drying rate of samples during sun drying of turmeric is given in APPENDIX-F2. The relationship between drying rate and drying time was determined to be non-linear, with the initial stage of drying showing a decrease in rates compared to the later stages of drying. Similar types of trends were also observed for other blanching treatments as shown in Fig. 4.50 to Fig. 4.52. It was observed that the drying rate increase was relatively higher for treatment B₂M₃S₂D₂ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-5 mm) and B₂M₃S₁D₂ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-4 mm) in comparison to B₂M₁S₃D₂ (Blanching temperature-80°C, Blanching time-15 min, and Slice thickness-whole). It was observed that drying rates increased with a decrease in slice thickness of turmeric. Standard practice of blanching was done on the samples before drying. This increases the drying rate as samples are partially cooked and some cells or tissues of rhizome might be disrupted or loosened (Bala 1997). As a result, moisture diffusion was higher and hence the drying rate was higher. The effect becomes more prominent with the increase of the temperature

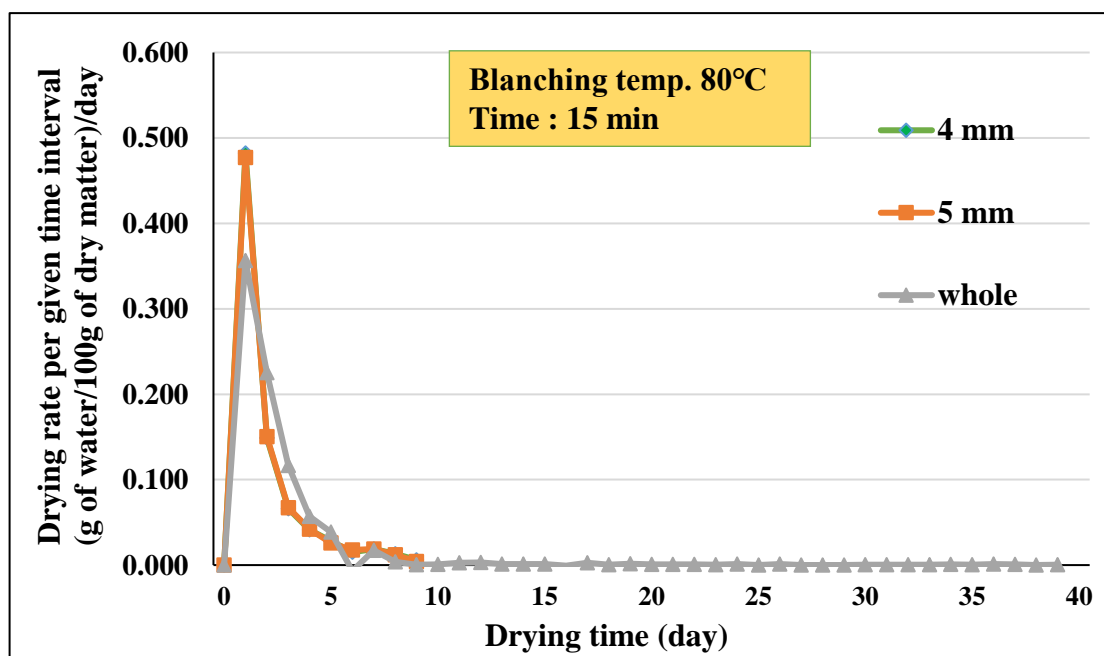


Fig. 4.50 Effect in the drying rate with drying time of turmeric blanched at 80°C for 15 min using sun drying

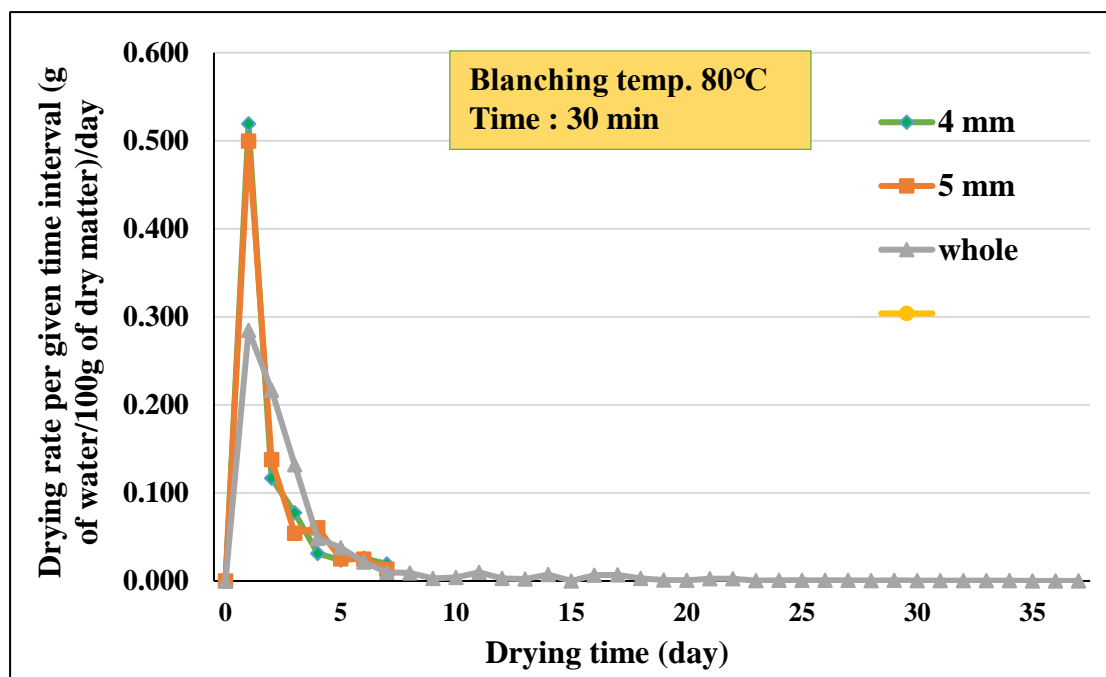


Fig. 4.51 Effect in the drying rate with drying time of turmeric blanching at 80°C for 30 min using sun drying

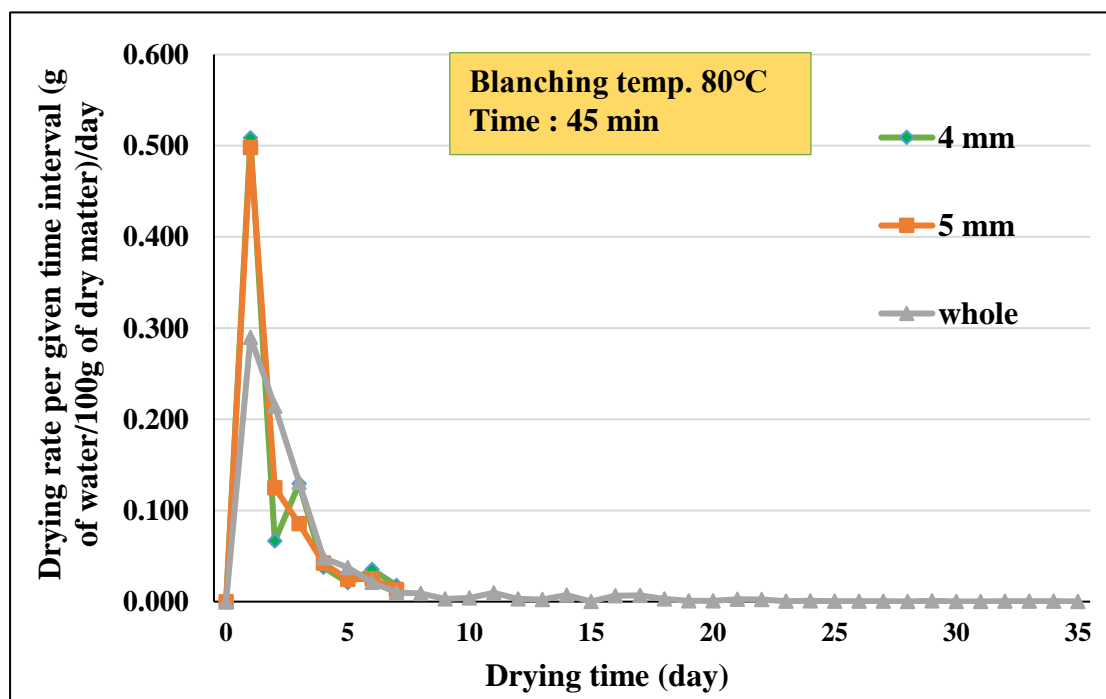


Fig. 4.52 Effect in the drying rate with drying time of turmeric blanching at 80°C for 45 min using sun drying

3) Moisture ratio (MR) of blanched sliced and whole turmeric vs. drying time

The moisture ratio of samples during sun drying of turmeric is given in APPENDIX-F3 as well a graphical representation of moisture ratio (MR) with respect to drying time is illustrated in Fig. 4.53 to Fig. 4.55.

This observation is evident from Fig. 4.53 to Fig. 4.55. Notably, the lower moisture ratios were observed in the treatment B₂M₃S₁D₂ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-4 mm) and B₂M₃S₂D₂ (i.e., Blanching temperature-80°C, Blanching time-45 min, and Slice thickness-5 mm) while the higher moisture ratios were observed in the treatment B₂M₁S₃D₂ (Blanching temperature-80°C, Blanching time-15 min, and Slice thickness-whole). While the moisture rate variations were almost similar for the B₂M₃S₁D₂ and B₂M₃S₂D₂ treatments, the B₂M₁S₃D₂ treatment showed the higher moisture ratios duration for the drying process. The results indicate that the moisture ratios of whole rhizomes are influenced by the blanching time and temperature, with lower blanching temperatures and shorter blanching times resulting in higher moisture ratios. This was observed in turmeric samples with lower slice thickness and higher blanching temperatures showing lower moisture ratios.

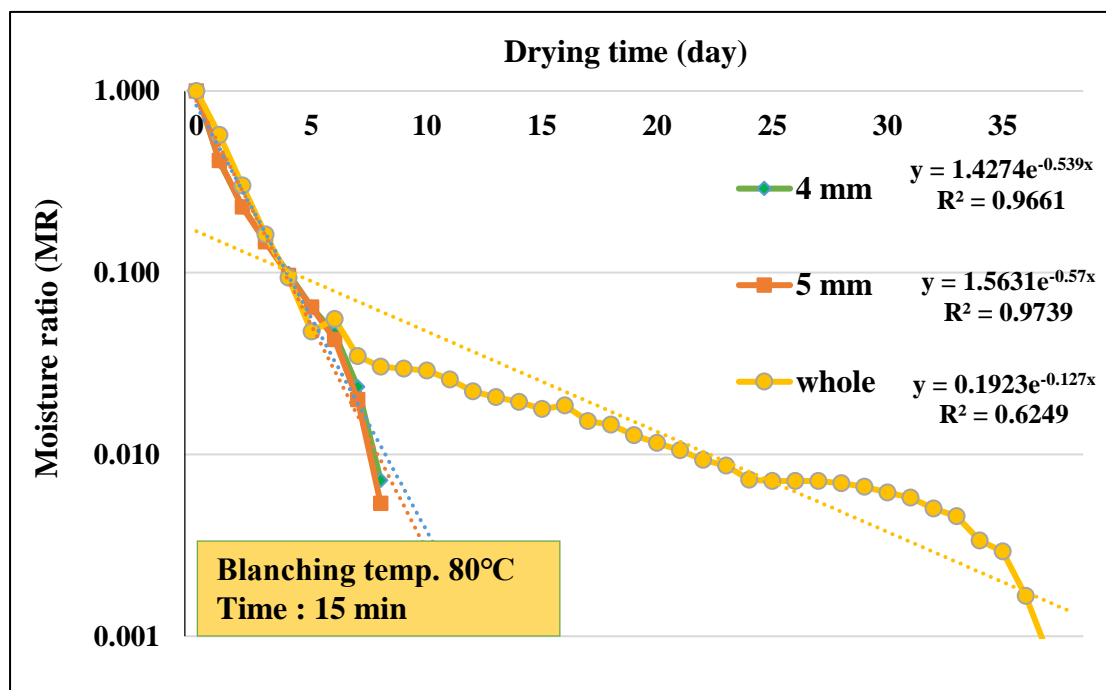


Fig. 4.53 Effect in the moisture ratio with drying time of turmeric blanched at 80°C for 15 min using sun drying

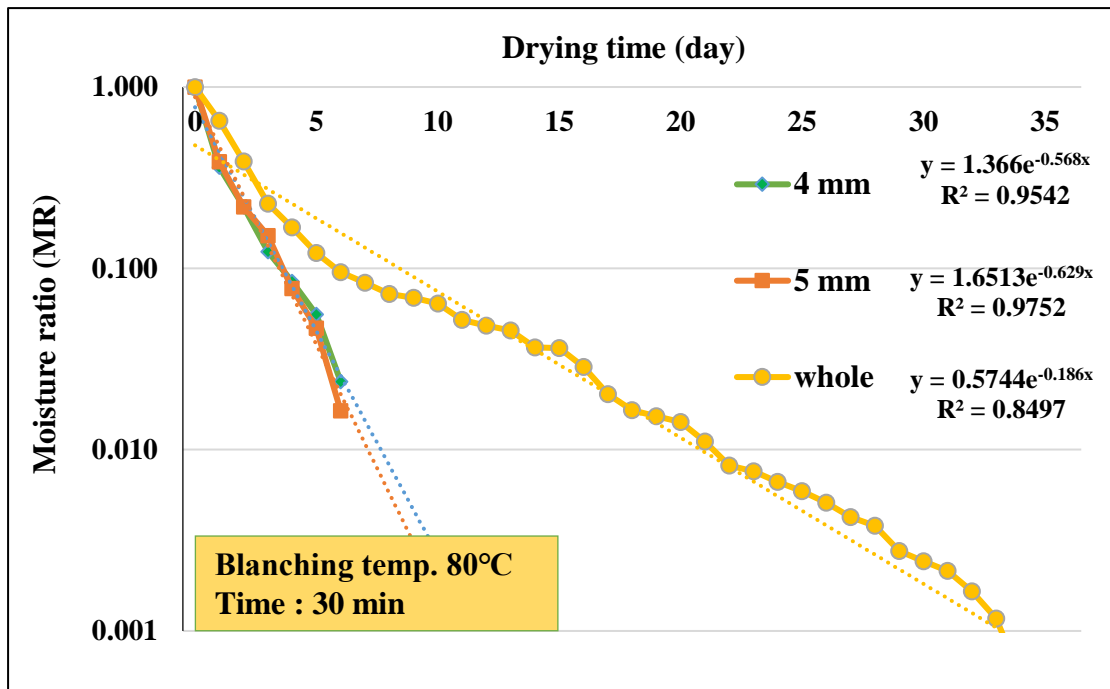


Fig. 4.54 Effect in the moisture ratio with drying time of turmeric blanching at 80°C for 30 min using sun drying

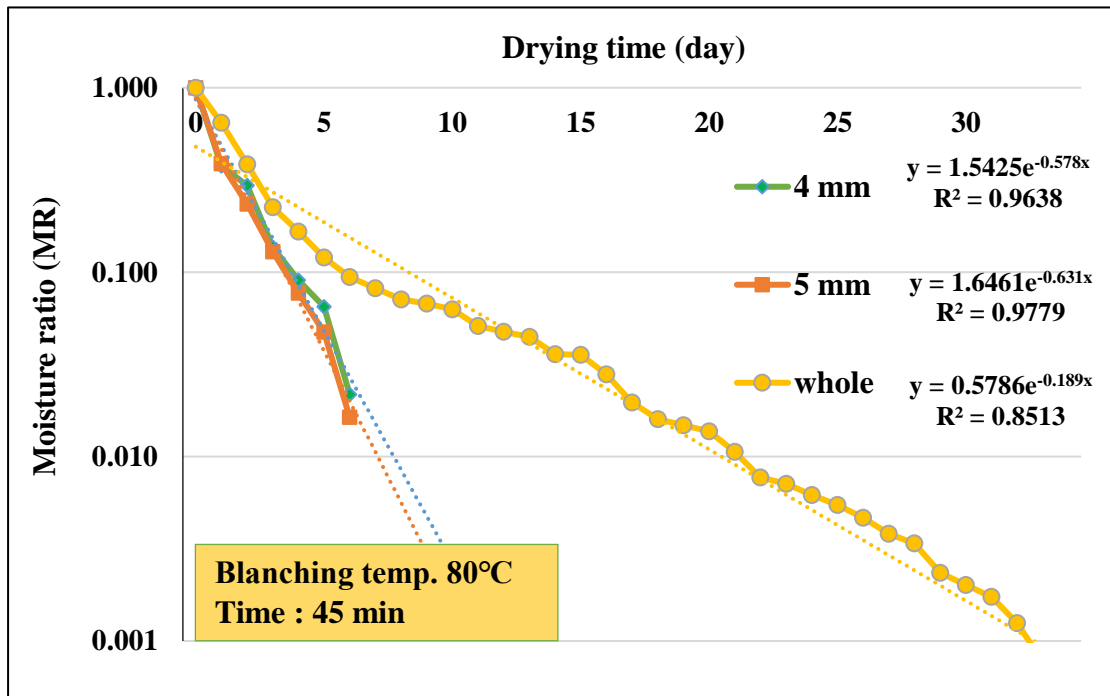


Fig. 4.55 Effect in the moisture ratio with drying time of turmeric blanching at 80°C for 45 min using sun drying

The moisture ratio of blanched turmeric slices and whole was decreased exponentially with the drying time. In the initial stage, the moisture ratio dropped faster and it slowed down in the later stages of drying irrespective of treatments (Velappan *et al.*, 1993).

4) Treatments of blanched sliced and whole turmeric vs. drying time

The drying time for the different samples of blanched turmeric slices and the whole is given in the APPENDIX-F1 and the comparative view of drying time for the different treatments is graphically presented in Fig. 4.56. The maximum drying time was recorded as 39 days in treatment B₂M₁S₃D₂ (Blanching temperature = 80°C, Blanching time = 15 min, and Slice thickness = whole). While, the minimum drying time was found 7 days in treatment B₂M₂S₁D₂ (Blanching temperature = 80°C, Blanching time = 30 min, and Slice thickness = 4 mm), B₂M₂S₂D₂ (Blanching temperature = 80°C, Blanching time = 30 min, and Slice thickness = 5 mm), B₂M₃S₁D₂ (Blanching temperature = 80°C, Blanching time = 45 min, and Slice thickness = 4 mm) and B₂M₃S₂D₂ (Blanching temperature = 80°C, Blanching time = 45 min, and Slice thickness = 5 mm).

It was observed that blanching time and temperature significantly affected the drying time. As the blanching time and temperature increased the drying time was decreased (Jayashree and Zachariah 2018).

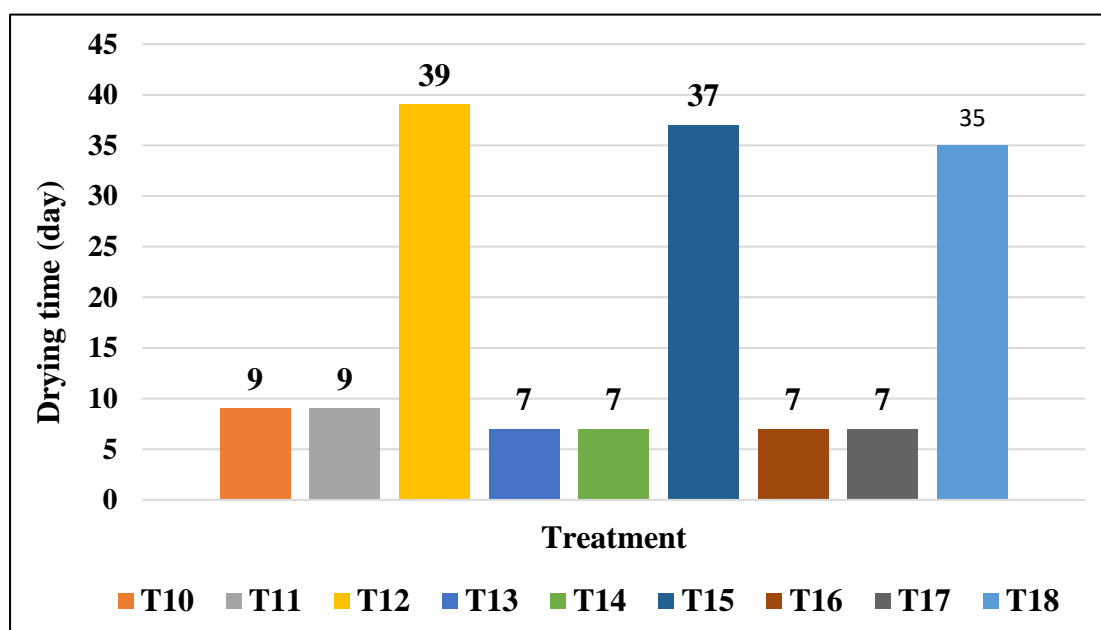


Fig. 4.56 Treatments with drying time during sun drying

4.7.2.3 Drying characteristics of blanched whole and sliced turmeric at 90°C

The details of treatment combinations are given in Table 3.2(b) of Chapter III

1) Moisture content of blanched sliced and whole turmeric vs. drying time

The moisture content of samples during sun drying of turmeric is given in APPENDIX-G1 as well a graphical representation of moisture content with respect to drying time is illustrated in Fig. 4.57 to Fig. 4.59. The relationship between moisture content and drying time was determined to be non-linear, in the initial stage of drying showing a larger decrease in moisture compared to the later stages. Similar type of trends were also observed for other blanching treatments as shown in Fig. 4.57 to Fig. 4.59. It was observed that the moisture content reduction was relatively higher for treatment B₃M₃S₁D₂ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-4 mm) and B₃M₃S₂D₂ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-5 mm) in comparison to B₃M₁S₃D₂ (Blanching temperature-90°C, Blanching time-15 min, and Slice thickness-whole). While the drying time variations were almost similar for the B₃M₃S₁D₂ and B₃M₃S₂D₂ treatments, the B₃M₁S₃D₂ treatment showed the longest duration for the drying process.

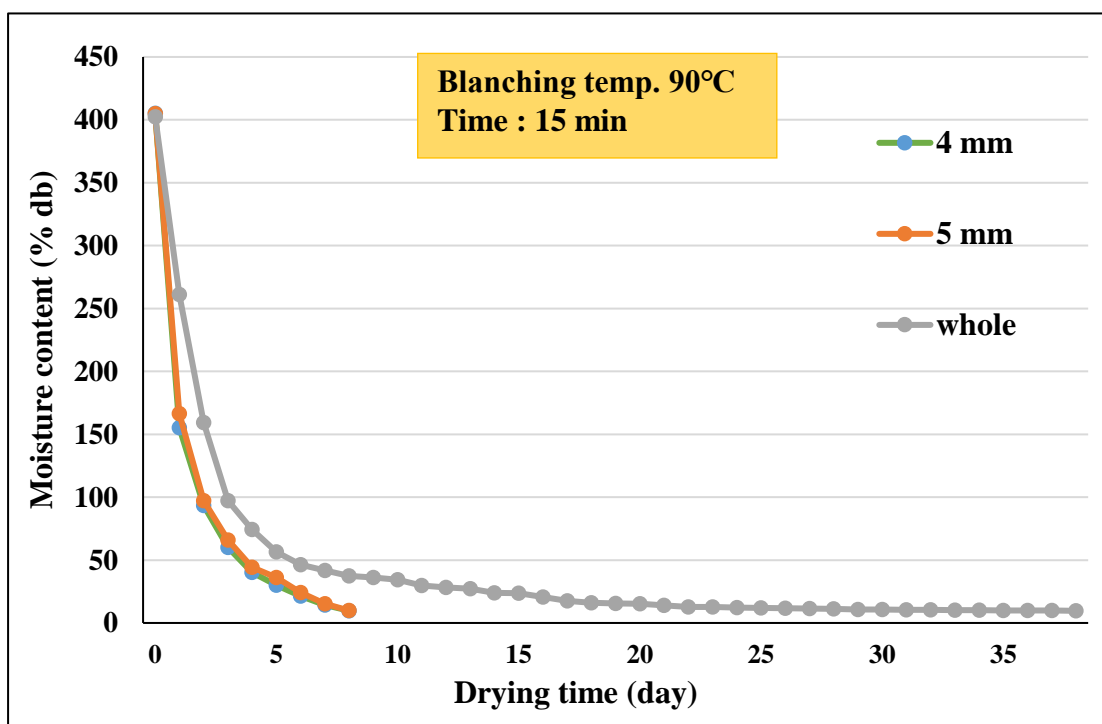


Fig. 4.57 Effect in the moisture content with drying time of turmeric blanched at 90°C for 15 min using sun drying

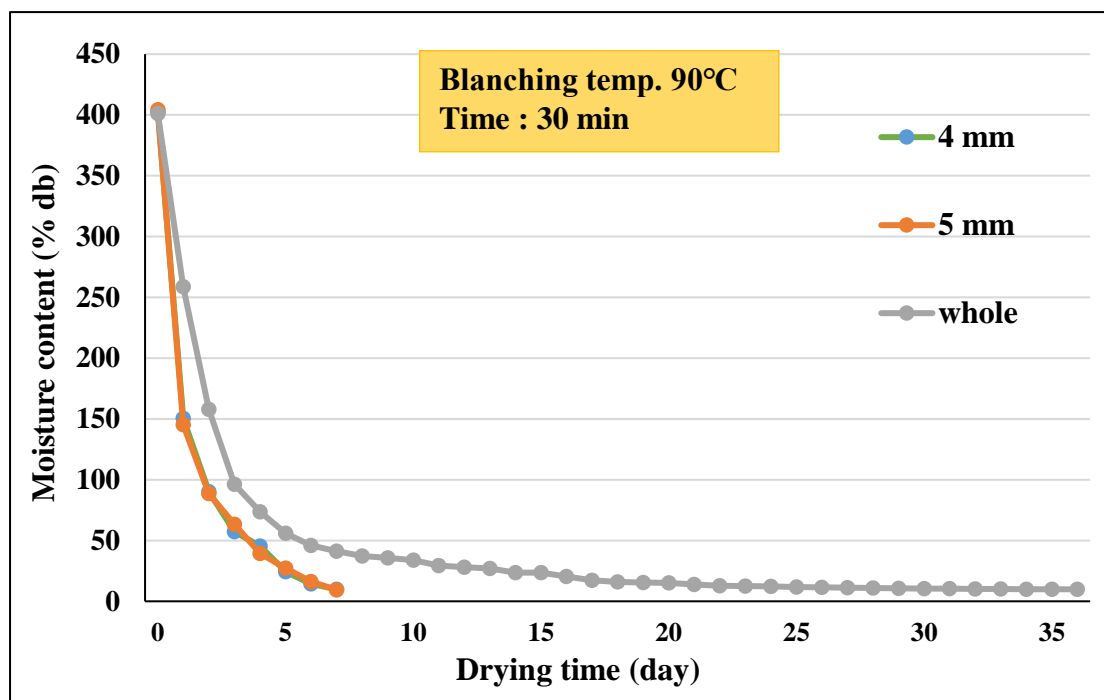


Fig. 4.58 Effect in the moisture content with drying time of turmeric blanching at 90°C for 30 min using sun drying

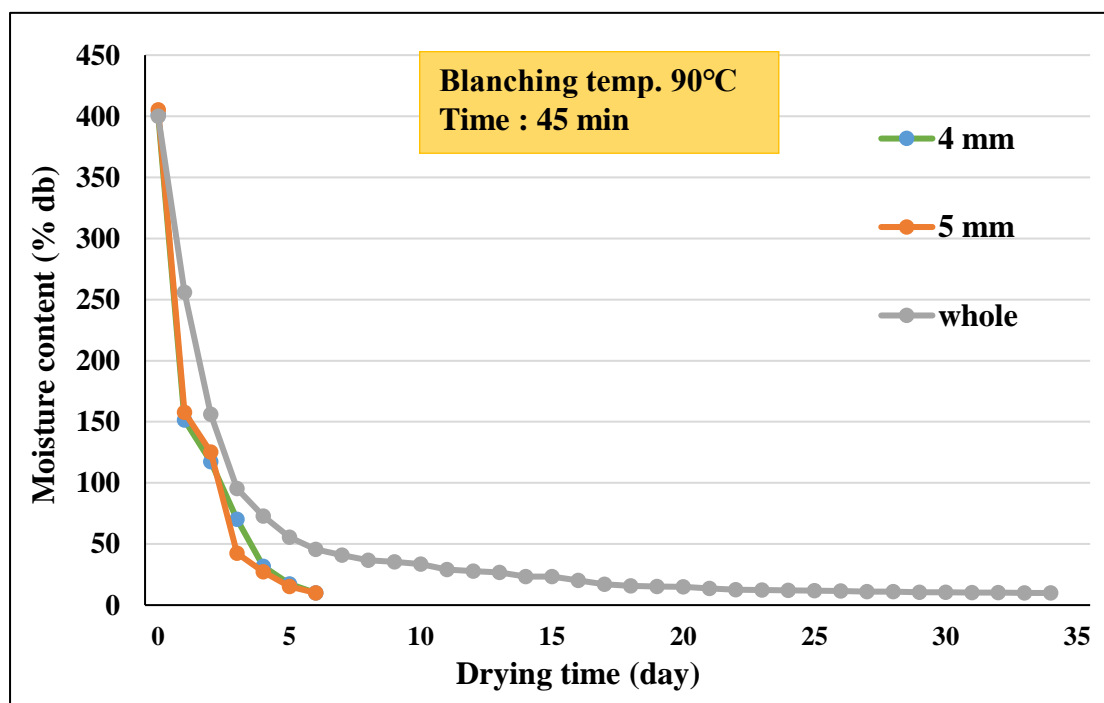


Fig. 4.59 Effect in the moisture content with drying time of turmeric blanching at 90°C for 45 min using sun drying

It was observed that the turmeric blanched at 90⁰C for 45 min, rate of moisture removal was faster in 4 mm, 5 mm and whole turmeric resulted in lower drying time, i.e., 6, 6 and 34 days, respectively. Followed by turmeric blanched at 90⁰C for 30 min and higher drying times at 90⁰C for 15 min treatments. This shows as the blanching time increased at constant blanching temperature (90⁰C), drying time decreased proportionately.

The turmeric in the solar dryer dried at a faster rate compared to sun drying. The turmeric in the solar dried at a faster rate mainly due to the higher temperature achieved in the dryer which causes higher diffusion of moisture from the interior to the surface of turmeric as compared to turmeric dried in ambient conditions (Gill *et al.*, 2021).

2) Drying rate of blanched sliced and whole turmeric vs. drying time

The drying rate of samples during sun drying of turmeric is given in APPENDIX-G2.

The relationship between drying rate and drying time was determined to be non-linear, with the initial stage of drying showing a decrease in rates compared to the later stages of drying. Similar types of trends were also observed for other blanching treatments as shown in Fig. 4.60 to Fig. 4.62.

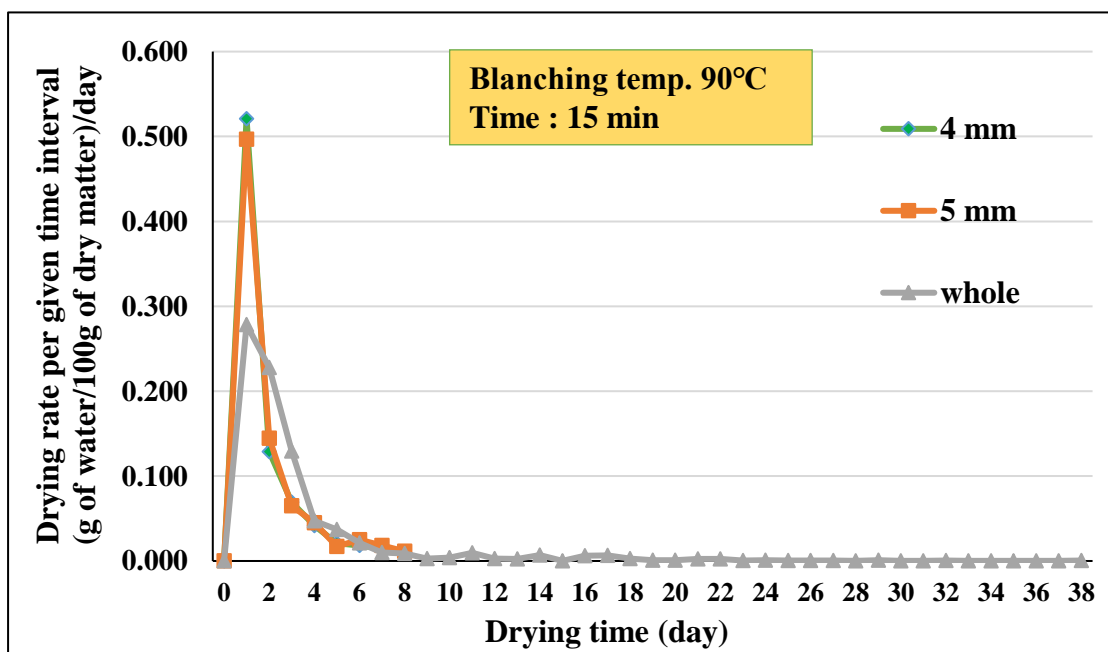


Fig. 4.60 Effect in the drying rate with drying time of turmeric blanched 90⁰C for 15 min using sun drying

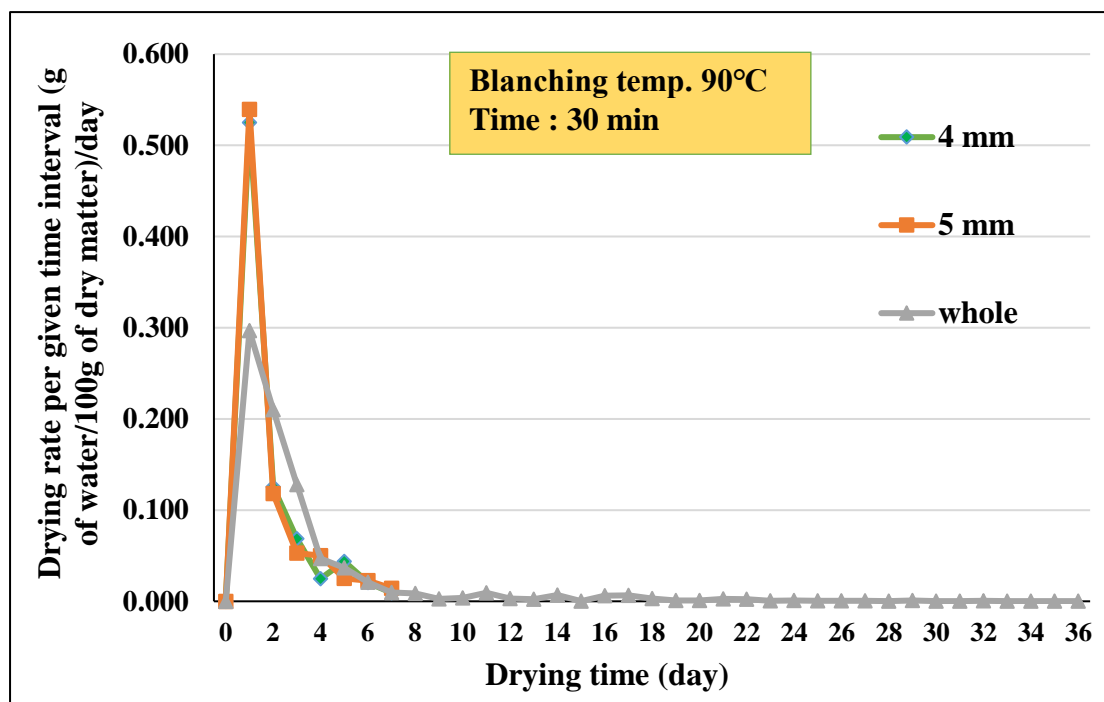


Fig. 4.61 Effect in the drying rate with drying time of turmeric blanching at 90°C for 30 min using sun drying

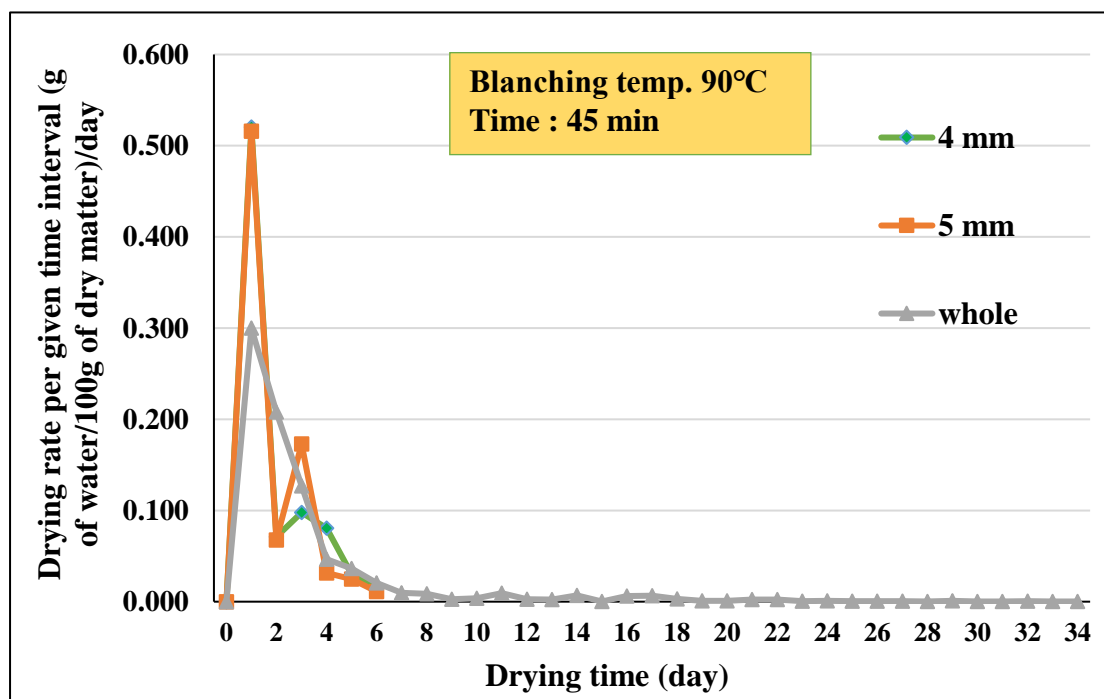


Fig. 4.62 Effect in the drying rate with drying time of turmeric blanching at 90°C for 45 min using sun drying

It was observed that the drying rate increase was relatively higher for treatment B₃M₃S₂D₂ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-5 mm) and B₃M₃S₁D₂ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-4 mm) in comparison to B₃M₁S₃D₂ (Blanching temperature-90°C, Blanching time-15 min, and Slice thickness-whole). It was observed that drying rates increased with a decrease in slice thickness of turmeric.

Drying occurred in the falling rate period for both samples. It could be seen that the rate of drying was much faster in the case of sliced samples in comparison to whole samples up to the end of the initial 7 h of drying. At this stage, the moisture content was found to be 14.23% and 26.52% (wb) of sliced and whole samples respectively, which was obvious, due to exposure of a more porous surface to the drying air in the case of sliced samples (Borah *et al.*, 2015).

3) Moisture ratio (MR) of blanched sliced and whole turmeric vs. drying time

The moisture ratio of samples during sun drying of turmeric is given in APPENDIX-G3.

The moisture ratio of blanched turmeric slices and whole was decreased exponentially with the drying time. In the initial stage, the moisture ratio dropped faster and it slowed down in the later stages of drying irrespective of treatments (Velappan *et al.*, 1993).

This observation is evident from Fig. 4.63 to Fig. 4.65. Notably, the lower moisture ratios were observed in the treatment B₃M₃S₁D₂ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-4 mm) and B₃M₃S₂D₂ (i.e., Blanching temperature-90°C, Blanching time-45 min, and Slice thickness-5 mm) while the higher moisture ratios were observed in the treatment B₃M₁S₃D₂ (Blanching temperature-90°C, Blanching time-15 min, and Slice thickness-whole). While the moisture rate variations were almost similar for the B₃M₃S₁D₂ and B₃M₃S₂D₂ treatments, the B₃M₁S₃D₂ treatment showed the higher moisture ratios duration for the drying process. The results indicate that the moisture ratios of whole rhizomes are influenced by the blanching time and temperature, with lower blanching temperatures and shorter blanching times resulting in higher moisture ratios. This was observed in turmeric samples with lower slice thickness and higher blanching temperatures show lower moisture ratios.

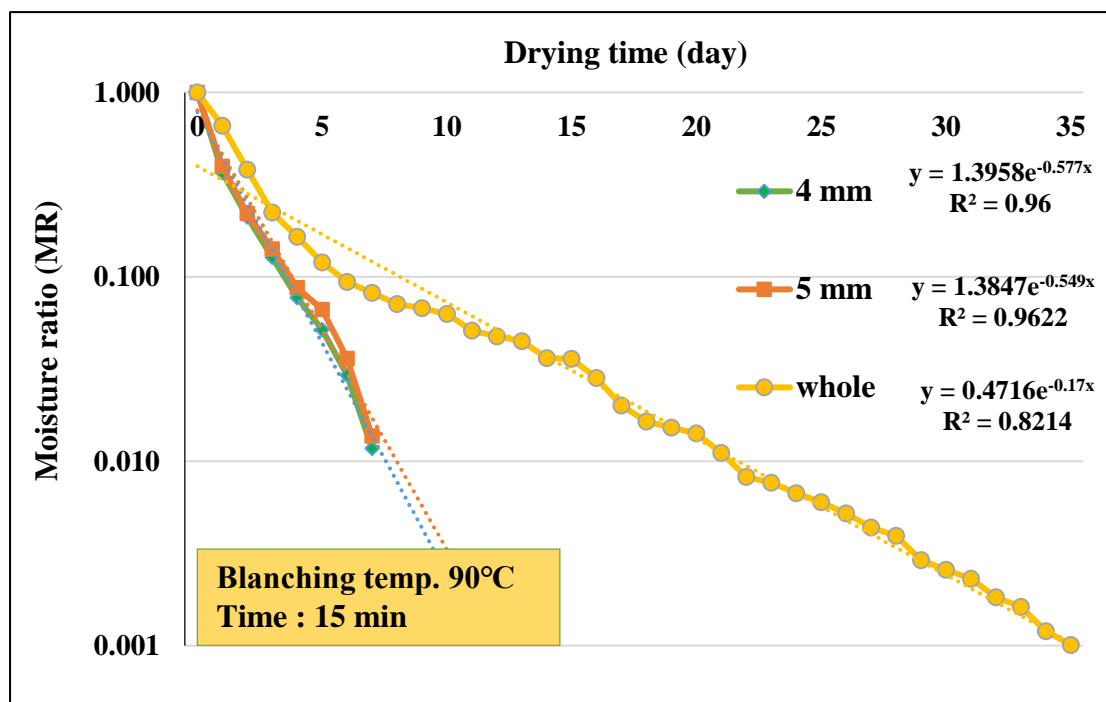


Fig. 4.63 Effect in the moisture ratio with drying time of turmeric blanching at 90°C for 15 min using sun drying

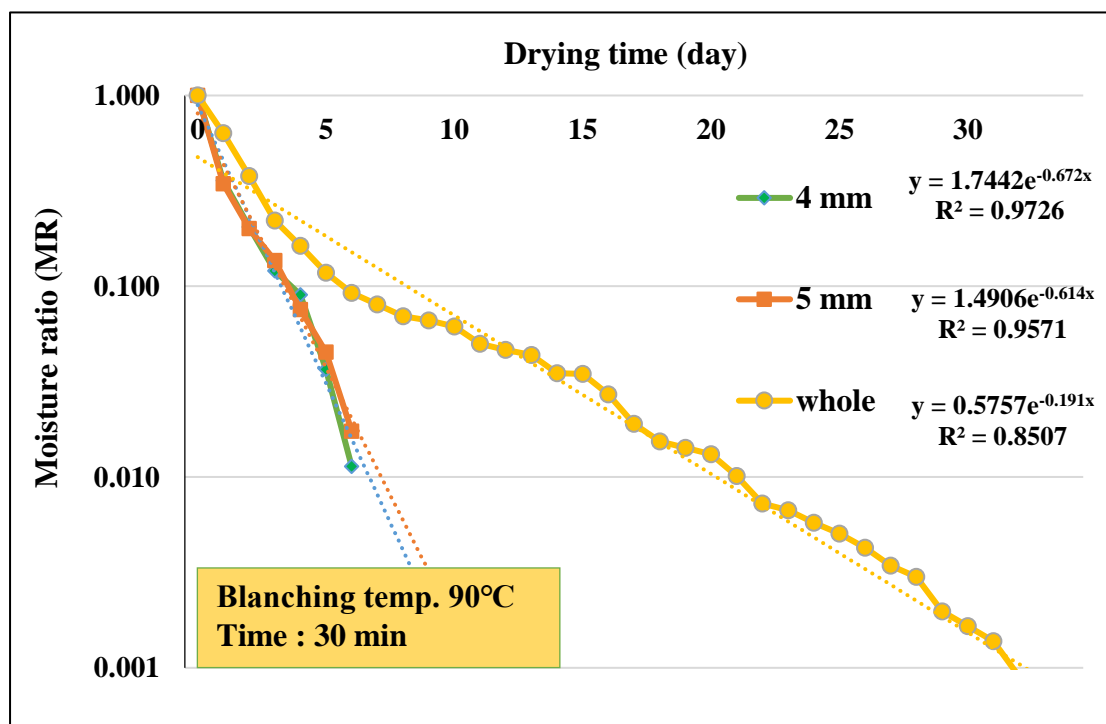


Fig. 4.64 Effect in the moisture ratio with drying time of turmeric blanching at 90°C for 30 min using sun drying

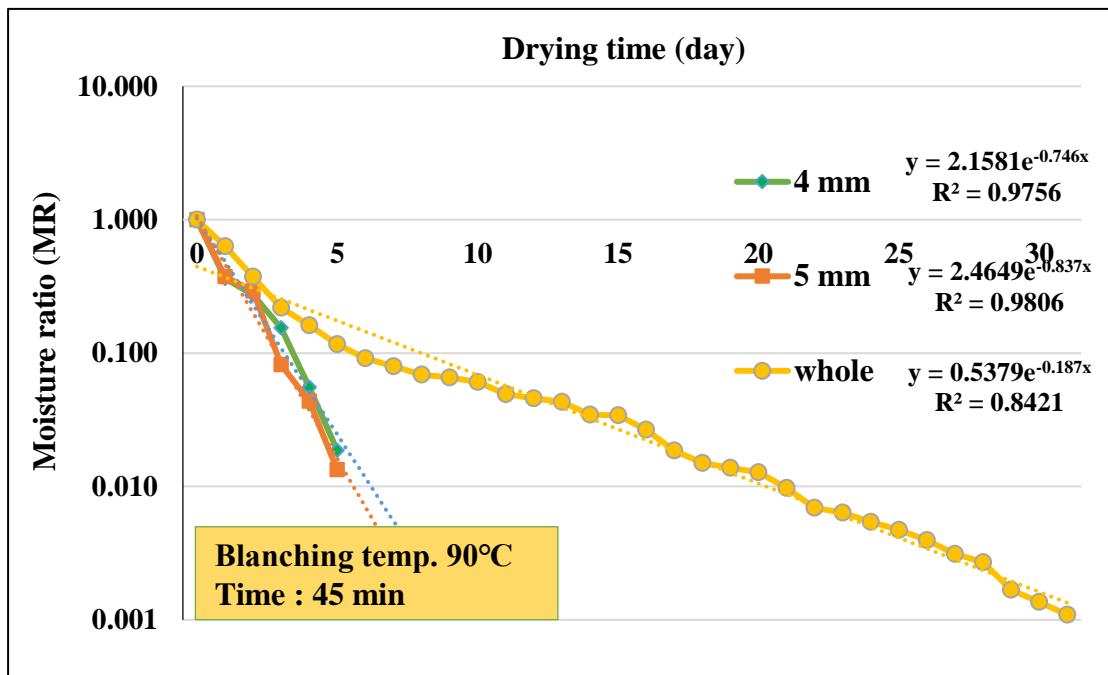


Fig. 4.65 Effect in the moisture ratio with drying time of turmeric blanching at 90°C for 45 min using sun drying

4) Effect in drying constant of dried turmeric

The values of the drying constant are an indication of the efficiency of the drying process. Table 4.6 revealed that the values of drying constant for 4 mm thicknesses were higher in all the treatments as compared to 5 mm sliced turmeric and whole rhizomes, i.e., as the thickness increases value of the drying constant decreases. Furthermore, blanching temperature and blanching time increase values of drying constant increases proportionately. In addition to these, the highest values of drying constants, viz., $0.577d^{-1}$, $0.672d^{-1}$ and $0.746d^{-1}$ for 4 mm slices thickness at 90°C & 15 min, 90°C & 30 min and 90°C & 45 min, respectively.

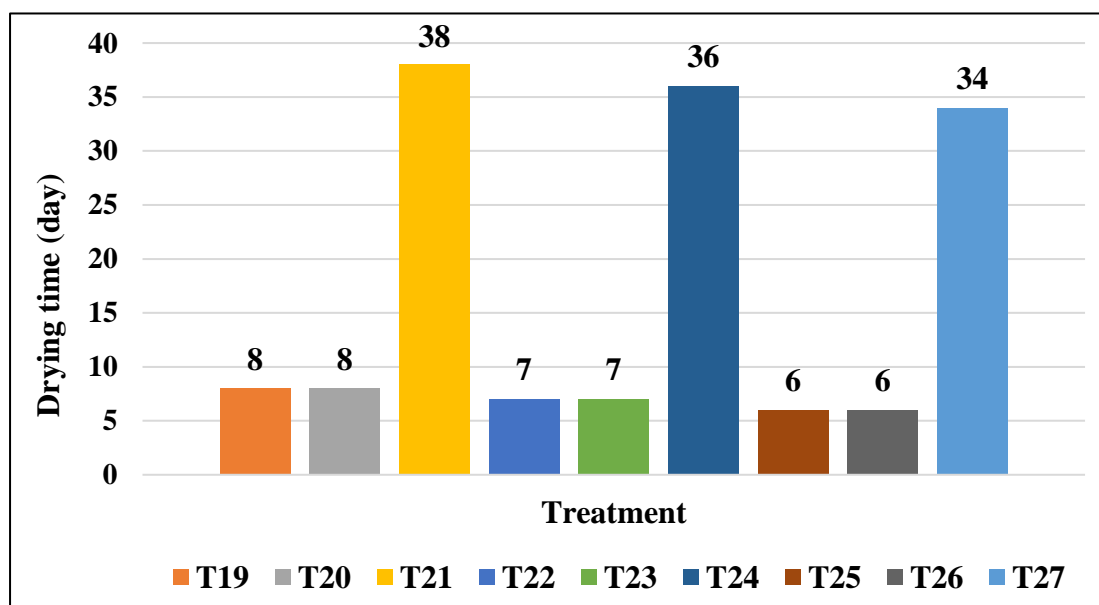
Followed by 5 mm thickness and lowest values of drying constants viz., $0.170d^{-1}$, $0.191d^{-1}$ and $0.187d^{-1}$ were obtained in all the treatments for whole turmeric rhizomes dried at 90°C & 15 min, 90°C & 30 min and 90°C & 45 min, respectively. However, very little variation in values of drying constant was observed in turmeric slices dried at 4 mm and 5 mm.

Table 4.6 Effect in drying constant of sun drying turmeric

| Sr. No. | Treatments | 4 mm | 5 mm | whole |
|---------|-------------------------------|-------|-------|-------|
| 1 | B ₁ M ₁ | 0.538 | 0.498 | 0.120 |
| 2 | B ₁ M ₂ | 0.530 | 0.521 | 0.120 |
| 3 | B ₁ M ₃ | 0.659 | 0.677 | 0.124 |
| 4 | B ₂ M ₁ | 0.539 | 0.570 | 0.120 |
| 5 | B ₂ M ₂ | 0.568 | 0.629 | 0.186 |
| 6 | B ₂ M ₃ | 0.578 | 0.631 | 0.189 |
| 7 | B ₃ M ₁ | 0.577 | 0.549 | 0.170 |
| 8 | B ₃ M ₂ | 0.672 | 0.614 | 0.191 |
| 9 | B ₃ M ₃ | 0.746 | 0.837 | 0.187 |

4) Treatments of blanched sliced and whole turmeric vs. drying time

The drying time for the different samples of blanched turmeric slices and whole is given in APPENDIX-G1 and the comparative view of drying time for the different treatments is graphically presented in Fig. 4.66. The maximum drying time was recorded as 38 days in treatment B₃M₁S₃D₂ (Blanching temperature = 90°C, Blanching time = 15 min, and Slice thickness = whole). While, the minimum drying time was found 6 days in treatment B₃M₃S₁D₂ (Blanching temperature = 90°C, Blanching time = 45 min, and Slice thickness = 4 mm) and B₃M₃S₂D₂ (Blanching temperature = 90°C, Blanching time = 45 min, and Slice thickness = 5 mm).

**Fig. 4.66 Treatments with drying time during sun drying**

It was observed that blanching time and temperature significantly affected the drying time. As the blanching time and temperature increased the drying time was decreased. Blanching for a longer duration softens the tissues and enhances the removal of water at a faster rate thus reduced the drying time (Jayashree and Zachariah 2018).

It was observed that blanching time and temperature significantly affected the drying time. As the blanching time and temperature increased the drying time was decreased. Blanching for a longer duration softens the tissues and enhances the removal of water at a faster rate thus reduced the drying time (Jayashree and Zachariah 2018).

4.7.3 The effect of blanching process on drying characteristics of turmeric

Solar Tunnel Drying

The drying times for turmeric slices varied significantly depending on the treatment conditions applied. For treatment B₁M₁S₃D₁ (Blanching temperature = 70°C, Blanching time = 15 min), the maximum drying time observed was 22 days, while the minimum was 6 days when using a 45-minute blanching time, 70°C blanching temperature and 4 mm, 5 mm slice thickness (B₁M₃S₁D₁ and B₁M₃S₂D₁), respectively.

Similarly, for treatment B₂M₁S₃D₁ (Blanching temperature = 80°C, Blanching time = 15 min), the maximum drying time was 21 days, with the minimum of 5 days observed in treatments B₂M₃S₁D₁ and B₂M₃S₂D₁, both with a 45-minute blanching time, 80°C blanching temperature and 4 mm, 5 mm slice thickness, respectively.

For treatment B₃M₁S₃D₁ (Blanching temperature = 90°C, Blanching time = 15 min), the maximum drying time was 19 days, while the minimum was 5 days in treatments B₃M₃S₁D₁ and B₃M₃S₂D₁, both using a 45-minute blanching time, 90°C blanching temperature and 4 mm, 5 mm slice thickness, respectively.

Sun Drying

The drying times for turmeric slices varied significantly depending on the treatment conditions applied. For treatment B₁M₁S₃D₂ (Blanching temperature = 70°C, Blanching time = 15 min), the maximum drying time observed was 40 days, while the minimum was 7 days when using a 45-minute blanching time, 70°C blanching temperature and 4 mm, 5 mm slice thickness (B₁M₃S₁D₂ and B₁M₃S₂D₂), respectively.

Similarly, for treatment B₂M₁S₃D₂ (Blanching temperature = 80°C, Blanching time = 15 min), the maximum drying time was 39 days, with the minimum of 7 days observed in treatments B₂M₃S₁D₂ and B₂M₃S₂D₂, both with a 45-minute blanching time, 80°C blanching temperature and 4 mm, 5 mm slice thickness, respectively.

For treatment B₃M₁S₃D₂ (Blanching temperature = 90°C, Blanching time = 15 min), the maximum drying time was 38 days, while the minimum was 6 days in treatments B₃M₃S₁D₁ and B₃M₃S₂D₁, both using a 45-minute blanching time, 90°C blanching temperature and 4 mm, 5 mm slice thickness, respectively.

4.8 Biochemical analysis of dried turmeric

4.8.1 Biochemical analysis of dried turmeric by STD and SD

4.8.1.1 Moisture content

4.8.1.1.1 Effect of pretreatments and drying methods on moisture content

The moisture content of sliced and whole turmeric is influenced by blanching temperature, time and drying methods. The values of moisture content at different drying methods (i.e., solar tunnel drying and sun drying), blanching temperature (70°C, 80°C and 90°C), and blanching time (15 min, 30 min and 45 min) are presented in Table 4.7.

Table 4.8 Treatment wise values of moisture content for dried turmeric

| Sr. No. | Treatments | 4 mm (S ₁) | | 5 mm (S ₂) | | whole (S ₃) | |
|---------|-------------------------------|------------------------|----------------------|------------------------|----------------------|-------------------------|----------------------|
| | | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD |
| 1 | B ₁ M ₁ | 9.81 | 9.84 | 9.77 | 9.81 | 9.73 | 9.77 |
| 2 | B ₁ M ₂ | 9.85 | 9.89 | 9.84 | 9.88 | 9.81 | 9.84 |
| 3 | B ₁ M ₃ | 9.90 | 9.95 | 9.90 | 9.91 | 9.84 | 9.87 |
| 4 | B ₂ M ₁ | 9.85 | 9.85 | 9.85 | 9.87 | 9.77 | 9.82 |
| 5 | B ₂ M ₂ | 9.88 | 9.90 | 9.91 | 9.91 | 9.80 | 9.89 |
| 6 | B ₂ M ₃ | 9.95 | 9.96 | 9.93 | 9.94 | 9.86 | 9.94 |
| 7 | B ₃ M ₁ | 9.93 | 9.91 | 9.87 | 9.9 | 9.80 | 9.85 |
| 8 | B ₃ M ₂ | 9.96 | 9.95 | 9.92 | 9.95 | 9.90 | 9.91 |
| 9 | B ₃ M ₃ | 9.97 | 9.98 | 9.97 | 9.99 | 9.96 | 9.97 |

Table 4.7 Effect of drying method, blanching temperatures and time on moisture content of sliced and whole dried turmeric rhizomes

| Moisture content (% wb) | | | |
|----------------------------------|------------|------------|--------------|
| Treatment | 4mm | 5mm | whole |
| Drying methods (D) | | | |
| D₁ (STD) | 9.90 | 9.88 | 9.83 |
| D₂ (SD) | 9.91 | 9.91 | 9.87 |
| S.Em.± | 0.09 | 0.10 | 0.10 |
| C.D. at 5 % | NS | NS | NS |
| Blanching temperature (B) | | | |
| B₁ (70°C) | 9.87 | 9.85 | 9.81 |
| B₂ (80°C) | 9.90 | 9.90 | 9.85 |
| B₃ (90°C) | 9.95 | 9.93 | 9.90 |
| S.Em.± | 0.11 | 0.13 | 0.12 |
| C.D. at 5 % | NS | NS | NS |
| Blanching time (M) | | | |
| M₁ (15 min.) | 9.87 | 9.85 | 9.79 |
| M₂ (30 min.) | 9.91 | 9.90 | 9.86 |
| M₃ (45 min.) | 9.95 | 9.94 | 9.91 |
| S.Em.± | 0.11 | 0.13 | 0.12 |
| C.D. at 5 % | NS | NS | NS |
| C.V. % | 3.90 | 4.48 | 4.24 |
| D X B | | | |
| S.Em.± | 0.16 | 0.18 | 0.17 |
| C.D. at 5 % | NS | NS | NS |
| D X M | | | |
| S.Em.± | 0.16 | 0.18 | 0.17 |
| C.D. at 5 % | NS | NS | NS |
| B X M | | | |
| S.Em.± | 0.19 | 0.22 | 0.21 |
| C.D. at 5 % | NS | NS | NS |
| D X B X M | | | |
| S.Em.± | 0.27 | 0.31 | 0.30 |
| C.D. at 5 % | NS | NS | NS |

1) Effect of drying methods and slice thickness (4 mm) on moisture content

The treatment wise values of moisture content of dried turmeric are tabulated in the Table 4.8 and the comparative view of moisture content of dried turmeric for the different drying treatments is graphically presented in Fig. 4.67.

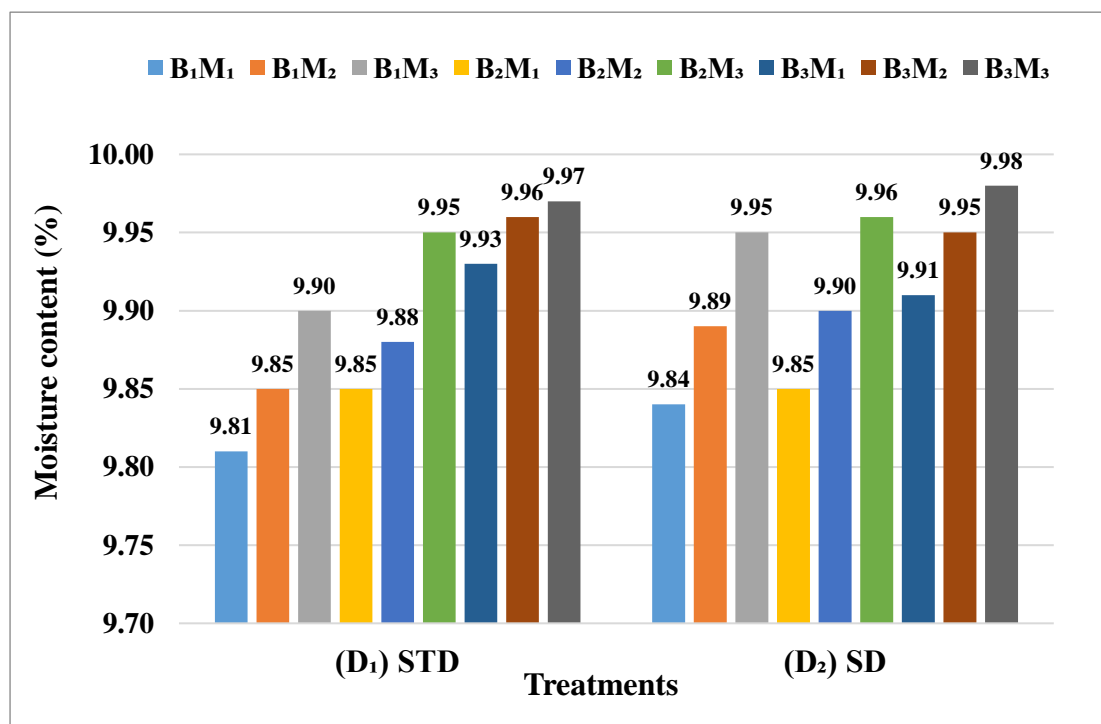


Fig. 4.67 Effect in the moisture content of dried turmeric for the different drying treatments

From Fig. 4.67, it can be shown that the maximum moisture content (9.98%) was obtained in the treatment B₃M₃S₁D₂ (Blanching temperature= 90°C, Blanching time= 45 min and thickness= 4 mm) while the minimum moisture content (9.81%) was obtained in the treatment B₁M₁S₁D₁ (Blanching temperature= 70°C, Blanching time= 15 min and thickness= 4 mm).

2) Effect of drying methods and slice thickness (5 mm) on moisture content

The treatment wise values of moisture content of dried turmeric are tabulated in the Table 4.8 and the comparative view of moisture content of dried turmeric for the different drying treatments is graphically presented in Fig. 4.68.

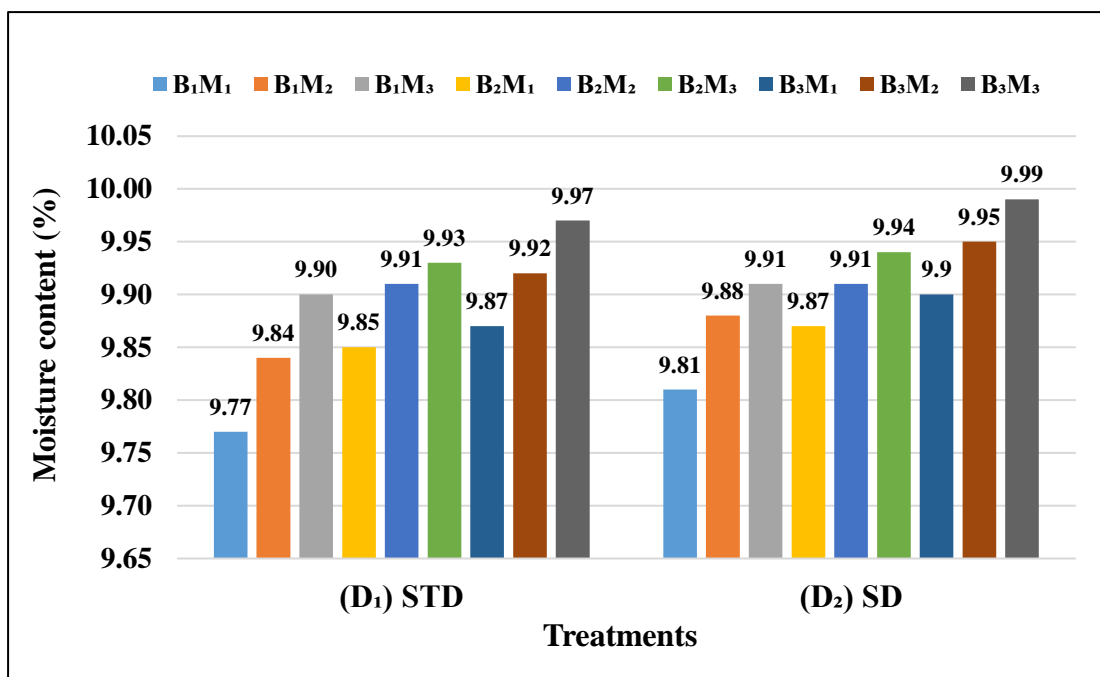


Fig. 4.68 Effect in the moisture content of dried turmeric for the different drying treatments

From Fig. 4.68, it can be shown that the maximum moisture content (9.99%) was obtained in the treatment B₃M₃S₂D₂ (Blanching temperature= 90°C, Blanching time= 45 min and thickness= 5 mm) while the minimum moisture content (9.77%) was obtained in the treatment B₁M₁S₂D₁ (Blanching temperature= 70°C, Blanching time= 15 min and thickness= 5 mm).

3) Effect of drying methods and slice thickness (whole) on moisture content

The treatment wise values of moisture content of dried turmeric are tabulated in the Table 4.8 and the comparative view of moisture content of dried turmeric for the different drying treatments is graphically presented in Fig. 4.69.

From Fig. 4.69, it can be shown that the maximum moisture content (9.97%) was obtained in the treatment B₃M₃S₃D₂ (Blanching temperature= 90°C, Blanching time= 45 min and thickness= whole) while the minimum moisture content (9.73%) was obtained in the treatment B₁M₁S₃D₁ (Blanching temperature= 70°C, Blanching time= 15 min and thickness= whole).

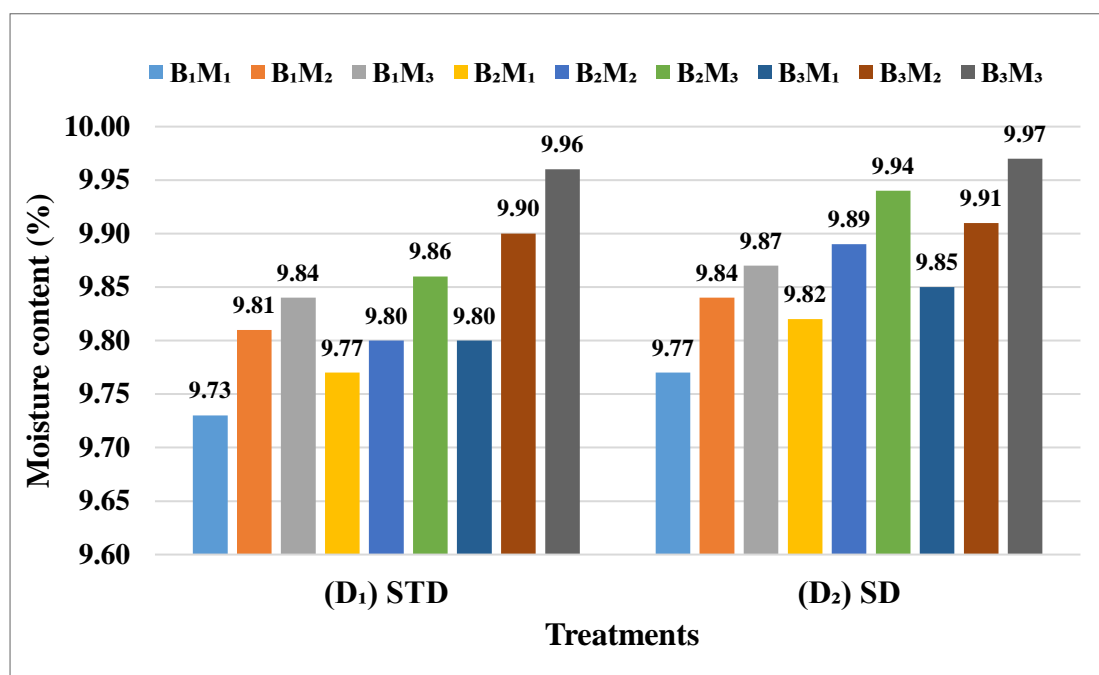


Fig. 4.69 Effect in the moisture content of dried turmeric for the different drying treatments

4.8.1.2 Total carbohydrate content

4.8.1.2.1 Effect of pretreatments and drying methods on total carbohydrate

The total carbohydrate of sliced and whole turmeric influenced by blanching temperature, time and drying methods. The value of total carbohydrate at different drying methods (i.e., solar tunnel drying and sun drying), blanching temperature (70°C, 80°C and 90°C), and blanching time (15 min, 30 min and 45 min) are presented in Table 4.9. The mean values of total carbohydrate are presented in APPENDIX-H1 and APPENDIX-H2, respectively. Effects of these process variables on total carbohydrate of turmeric are discussed hereunder.

1) Effect of drying methods and sliced thickness (4 mm) on total carbohydrate

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Table. 4.9) that highest value of total carbohydrate of 59.03% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total carbohydrate of 40.06% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.10) revealed that the effect of drying methods (D) was found significant on indicated that the solar tunnel drying increased the total carbohydrate of sliced turmeric. The total carbohydrate content of solar tunnel drying D₁ (49.99%) was significantly higher than that of sun drying method D₂ (46.59%).

Table 4.9 Effect of different blanching temperatures and times on total carbohydrate content of dried turmeric by different methods

| Sr. No. | Treatments | 4 mm | | 5 mm | | whole | |
|---------|-------------------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|----------------------|
| | | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD |
| 1 | B ₁ M ₁ | 59.03 | 52.30 | 60.24 | 53.10 | 63.41 | 55.31 |
| 2 | B ₁ M ₂ | 53.30 | 50.87 | 54.39 | 51.64 | 57.25 | 53.80 |
| 3 | B ₁ M ₃ | 48.51 | 45.36 | 49.50 | 46.05 | 52.11 | 47.97 |
| 4 | B ₂ M ₁ | 54.55 | 51.25 | 55.66 | 52.03 | 58.59 | 54.20 |
| 5 | B ₂ M ₂ | 49.74 | 46.45 | 50.75 | 47.15 | 53.42 | 49.12 |
| 6 | B ₂ M ₃ | 45.75 | 42.75 | 46.69 | 43.41 | 49.14 | 45.21 |
| 7 | B ₃ M ₁ | 50.63 | 47.34 | 51.67 | 48.06 | 54.39 | 50.06 |
| 8 | B ₃ M ₂ | 45.47 | 42.88 | 46.40 | 43.54 | 48.84 | 45.35 |
| 9 | B ₃ M ₃ | 42.89 | 40.06 | 43.77 | 40.67 | 46.07 | 42.37 |

2) Effect of blanching temperature and slice thickness (4 mm) on total carbohydrate

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that total carbohydrate of sliced turmeric decreased with increase in blanching temperature. The highest total carbohydrate of 59.03% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total carbohydrate of 40.06% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried). The analysed data (Table 4.10) also revealed that the effect of blanching temperature (B) was found significant. The total carbohydrate content of B₁ (51.56%) was significantly higher than that of B₂ (48.42%) and B₃ (44.88%).

Table 4.10 Effect of drying method, blanching temperatures and time on total Carbohydrate of sliced and whole dried turmeric rhizomes

| Total Carbohydrate | | | |
|----------------------------------|------------|------------|--------------|
| Treatment | 4mm | 5mm | whole |
| Drying methods (D) | | | |
| D₁ (STD) | 49.99 | 51.01 | 53.69 |
| D₂ (SD) | 46.59 | 47.30 | 49.27 |
| S.Em.± | 0.36 | 0.46 | 0.75 |
| C.D. at 5 % | 1.08 | 1.37 | 2.22 |
| Blanching temperature (B) | | | |
| B₁ (70°C) | 51.56 | 52.49 | 54.98 |
| B₂ (80°C) | 48.42 | 49.28 | 51.62 |
| B₃ (90°C) | 44.88 | 45.68 | 47.85 |
| S.Em.± | 0.44 | 0.56 | 0.91 |
| C.D. at 5 % | 1.32 | 1.67 | 2.71 |
| Blanching time (M) | | | |
| M₁ (15 min.) | 52.52 | 53.46 | 55.99 |
| M₂ (30 min.) | 48.12 | 48.98 | 51.30 |
| M₃ (45 min.) | 44.22 | 45.01 | 47.15 |
| S.Em.± | 0.44 | 0.56 | 0.91 |
| C.D. at 5 % | 1.32 | 1.67 | 2.71 |
| C.V. % | 3.19 | 3.97 | 6.15 |
| D X B | | | |
| S.Em.± | 0.63 | 0.80 | 1.29 |
| C.D. at 5 % | NS | NS | NS |
| D X M | | | |
| S.Em.± | 0.63 | 0.80 | 1.29 |
| C.D. at 5 % | NS | NS | NS |
| B X M | | | |
| S.Em.± | 0.77 | 0.98 | 1.58 |
| C.D. at 5 % | 1.64 | 1.47 | 1.88 |
| D X B X M | | | |
| S.Em.± | 1.09 | 1.38 | 2.24 |
| C.D. at 5 % | NS | NS | NS |

3) Effect of blanching time and slice thickness (4 mm) on total carbohydrate

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total carbohydrate increased with decrease in blanching time. The highest total carbohydrate of 59.03% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total carbohydrate of 40.06% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.3) also revealed that the significant effect of blanching time (M). The total carbohydrate content of M₁ (52.52%) was significantly higher than that of M₂ (48.12%) and M₃ (44.22%).

Carbohydrate contents increased with an increase in slice thickness, which may be attributed to minimal direct exposure to the drying conditions as the thickness increased (Korese *et al.*, 2022). Lokhande *et al.*, (2013) reported 65.80% carbohydrate for *Salem* variety. The values of carbohydrates found in this work are slightly lower than value reported by (Lokhande *et al.*, 2013). The difference may be due to locality, different temperature ranges and slice thickness, which were affect the carbohydrate.

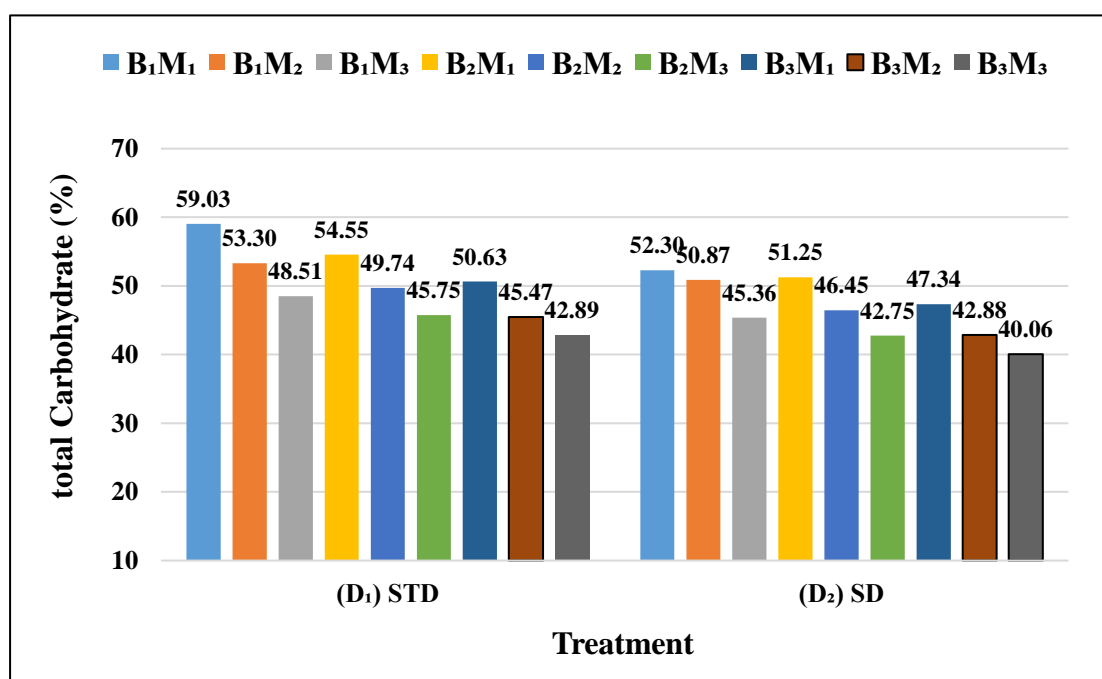


Fig. 4.70 Effect of different treatments on total carbohydrate of 4 mm slices turmeric

4) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total carbohydrate

The graphical presentation of the combined effect is shown in Fig. 4.70. The individual effect of D, B and M was found significant on the total carbohydrate of sliced turmeric (4 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.3). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

5) Effect of drying methods and sliced thickness (5 mm) on total carbohydrate

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.71) the total carbohydrate increased with solar tunnel drying methods. The highest total carbohydrate of 60.24% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total carbohydrate of 40.67% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried).

The analysed data (Table 4.10) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the total carbohydrate of sliced turmeric. The total carbohydrate of solar tunnel drying D₁ (51.01%) was significantly higher than that of sun drying method D₂ (47.30%).

6) Effect of blanching temperature and slice thickness (5 mm) on total carbohydrate

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that total carbohydrate of sliced turmeric increased with decrease in blanching temperature. The highest total carbohydrate of 60.24% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total carbohydrate of 40.67% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried).

The analysed data (Table 4.10) also revealed that the effect of blanching temperature (B) was found significant. The total carbohydrate of B₁ (52.49%) was significantly higher than that of B₂ (49.28%) and B₃ (45.68%).

7) Effect of blanching time and slice thickness (5 mm) on total carbohydrate

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total carbohydrate decreased with increase in blanching time. The highest total carbohydrate of 60.24% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total carbohydrate of 40.67% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried).

The analysed data (Table 4.3) also revealed that the significant effect of blanching time (M). The total carbohydrate of M₁ (53.46%) was significantly higher than that of M₂ (48.98%) and M₃ (45.01%).

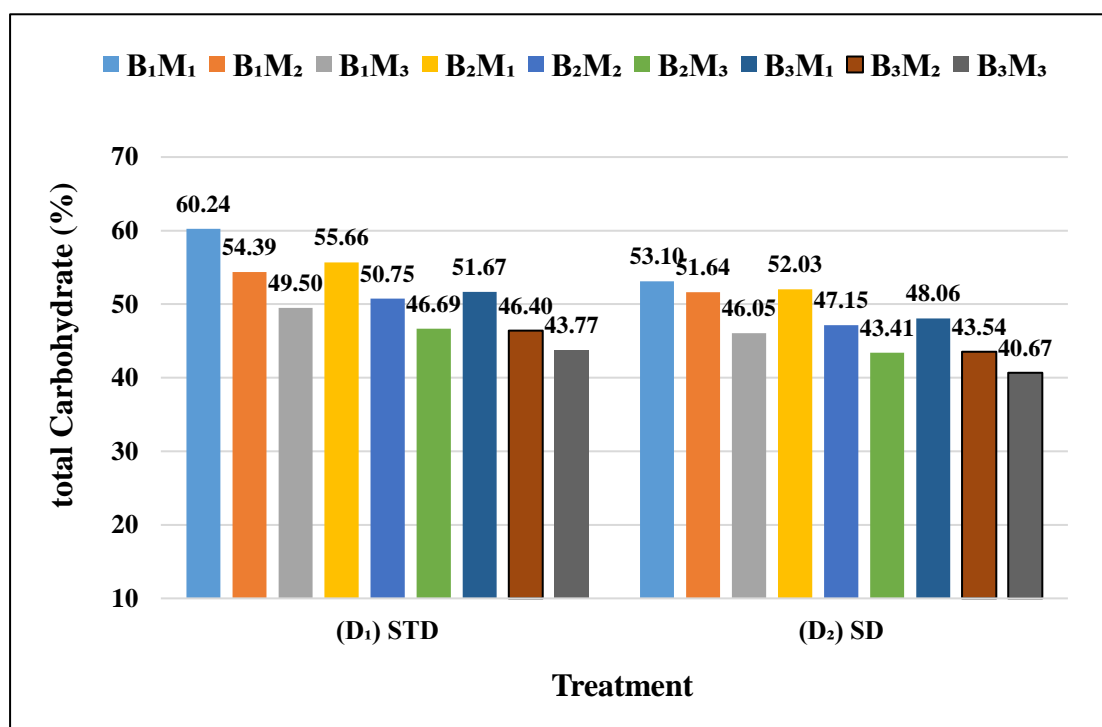


Fig. 4.71 Effect of different treatments on total carbohydrate of 5 mm slices turmeric

8) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total carbohydrate

The graphical presentation of the combined effect is shown in Fig. 4.71. The individual effect of D, B and M was found significant on the total carbohydrate of sliced

turmeric (5 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.10). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

An increase in carbohydrate, protein, and lipid contents content were observed after blanching (Gorinstein *et al.*, 2005). Carbohydrate and other organic materials vanishing during increases blanching time (Zerihun *et al.*, 2017).

9) Effect of drying methods and whole turmeric on total carbohydrate

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.72) the total carbohydrate increased with solar tunnel drying methods. The highest total carbohydrate of 63.41% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total carbohydrate of 42.37% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried).

The analysed data (Table 4.10) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the total carbohydrate of whole turmeric. The total carbohydrate of solar tunnel drying D₁ (53.69%) was significantly higher than that of sun drying method D₂ (49.27%).

10) Effect of blanching temperature and whole turmeric on total carbohydrate

The blanching of whole turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that total carbohydrate of whole turmeric decreased with increase in blanching temperature. The highest total carbohydrate of 63.41% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total carbohydrate of 42.37% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried).

The analysed data (Table 4.3) also revealed that the effect of blanching temperature (B) was found significant. The total carbohydrate of B₁ (54.98%) was significantly higher than that of B₂ (51.62%) and B₃ (47.85%).

11) Effect of blanching time and whole turmeric on total carbohydrate

The blanching of whole turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total carbohydrate decreased with increase in blanching time. The highest total carbohydrate of 63.41% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total carbohydrate of 42.37% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried).

Carbohydrate contents increased with an increase in slice thickness, which may be attributed to minimal direct exposure to the drying conditions as the thickness increased (Korese *et al.*, 2022). Lokhande *et al.*, (2013) reported 65.8% carbohydrate for salem variety. The values of carbohydrate found in this work are slightly lower than value reported by (Lokhande *et al.*, 2013). The difference may be due to locality, different temperature ranges and slice thickness, which were affect the carbohydrate.

The analysed data (Table 4.10) also revealed that the significant effect of blanching time (M). The total carbohydrate of M₁ (55.99%) was significantly higher than that of M₂ (51.30%) and M₃ (47.15%).

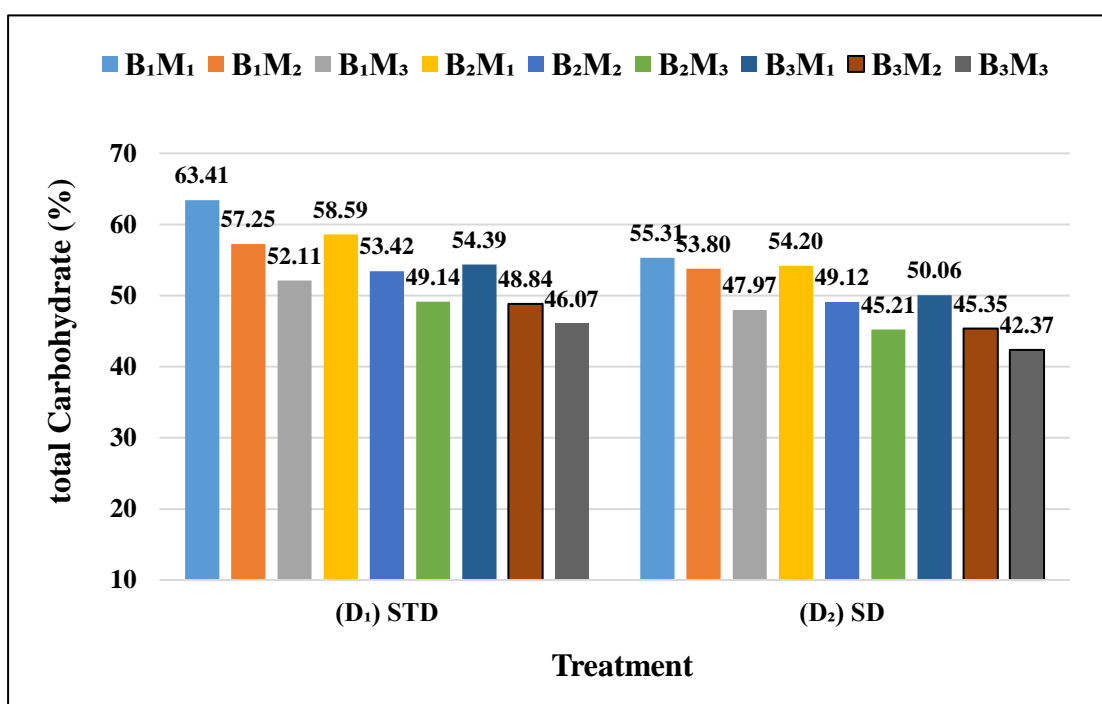


Fig. 4.72 Effect of different treatments on total carbohydrate of whole turmeric

12) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total carbohydrate

The graphical presentation of the combined effect is shown in Fig. 4.72. The individual effect of D, B and M was found significant on the of whole turmeric. However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.10). It may be the inherent nature of the factors. When interactions are non-significant, it means that levels of one factor are consistent over various levels of another factor.

4.8.1.3 True protein content

4.8.1.3.1 Effect of pretreatments and drying methods on true protein

The true protein of sliced and whole turmeric influenced by blanching temperature, time and drying methods. The value of true protein at different drying methods (i.e., solar tunnel drying and sun drying), blanching temperature (70°C, 80°C and 90°C), and blanching time (15 min, 30 min and 45 min) are presented in Table 4.11. The mean values of true protein are presented in APPENDIX-H1 and APPENDIX-H2, respectively. Effects of these process variables on true protein of turmeric are discussed hereunder.

Table 4.11 Effect of different blanching temperatures and times on true protein content of dried turmeric by different methods

| Sr. No. | Treatments | 4 mm | | 5 mm | | whole | |
|---------|-------------------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|----------------------|
| | | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD |
| 1 | B ₁ M ₁ | 9.51 | 8.66 | 10.01 | 9.12 | 9.07 | 8.23 |
| 2 | B ₁ M ₂ | 8.63 | 7.86 | 9.08 | 8.28 | 8.57 | 7.47 |
| 3 | B ₁ M ₃ | 7.93 | 7.18 | 8.30 | 7.56 | 7.89 | 6.82 |
| 4 | B ₂ M ₁ | 9.47 | 8.62 | 9.96 | 9.07 | 8.72 | 8.19 |
| 5 | B ₂ M ₂ | 8.48 | 7.71 | 8.92 | 8.11 | 8.39 | 7.32 |
| 6 | B ₂ M ₃ | 7.81 | 7.01 | 8.13 | 7.37 | 7.72 | 6.66 |
| 7 | B ₃ M ₁ | 9.33 | 8.49 | 9.82 | 8.94 | 8.62 | 8.07 |
| 8 | B ₃ M ₂ | 8.25 | 7.49 | 8.68 | 7.89 | 8.16 | 7.12 |
| 9 | B ₃ M ₃ | 7.73 | 6.90 | 7.98 | 7.27 | 7.58 | 6.56 |

Table 4.12 Effect of drying method, blanching temperatures and time on true protein of sliced and whole dried turmeric rhizomes

| True Protein | | | |
|----------------------------------|------------|------------|--------------|
| Treatment | 4mm | 5mm | whole |
| Drying methods (D) | | | |
| D₁ (STD) | 8.54 | 8.99 | 8.34 |
| D₂ (SD) | 7.77 | 8.18 | 7.38 |
| S.Em.± | 0.06 | 0.07 | 0.11 |
| C.D. at 5 % | 0.18 | 0.21 | 0.31 |
| Blanching temperature (B) | | | |
| B₁ (70°C) | 8.29 | 8.73 | 8.02 |
| B₂ (80°C) | 8.17 | 8.60 | 7.85 |
| B₃ (90°C) | 8.01 | 8.43 | 7.72 |
| S.Em.± | 0.07 | 0.09 | 0.13 |
| C.D. at 5 % | 0.22 | 0.26 | 0.38 |
| Blanching time (M) | | | |
| M₁ (15 min.) | 9.01 | 9.49 | 8.48 |
| M₂ (30 min.) | 8.07 | 8.49 | 7.85 |
| M₃ (45 min.) | 7.38 | 7.77 | 7.25 |
| S.Em.± | 0.07 | 0.09 | 0.13 |
| C.D. at 5 % | 0.22 | 0.26 | 0.38 |
| C.V. % | 3.18 | 3.56 | 5.69 |
| D X B | | | |
| S.Em.± | 0.11 | 0.12 | 0.18 |
| C.D. at 5 % | NS | NS | NS |
| D X M | | | |
| S.Em.± | 0.11 | 0.12 | 0.18 |
| C.D. at 5 % | NS | NS | NS |
| B X M | | | |
| S.Em.± | 0.13 | 0.15 | 0.22 |
| C.D. at 5 % | 0.34 | 0.15 | 0.27 |
| D X B X M | | | |
| S.Em.± | 0.18 | 0.22 | 0.32 |
| C.D. at 5 % | NS | NS | NS |

1) Effect of drying methods and sliced thickness (4 mm) on true protein

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.73) that true protein increased with solar tunnel

drying methods. The highest true protein of 9.51% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest true protein of 6.90% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.12) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the true protein of sliced turmeric. The true protein content of solar tunnel drying D₁ (8.54%) was significantly higher than that of sun drying method D₂ (7.77%).

2) Effect of blanching temperature and sliced thickness 4 mm on true protein

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that true protein of sliced turmeric decreased with increase in blanching temperature. The highest true protein of 9.51% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest true protein of 6.90% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried). The analysed data (Table 4.12) also revealed that the effect of blanching temperature (B) was found significant. The true protein content of B₁ (8.29%) was significantly higher than that of B₂ (8.17%) and B₃ (8.01%)

3) Effect of blanching time and slice thickness (4 mm) on true protein

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that true protein decreased with increase in blanching. The highest true protein of 9.51% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest true protein of 6.90% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.12) also revealed that the significant effect of blanching time (M). The true protein content of M₁ (9.01%) was significantly higher than that of M₂ (8.07%) and M₃ (7.38%).

High temperature and prolonged drying results in protein denaturation which accounts for the decrease in protein as slice thickness increased (Korese and

Achaglinkame, 2022). However, protein decreased as slice thickness increased. This is because the whole turmeric took a longer time to dry as compared to the slice samples.

4) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on true protein

The graphical presentation of the combined effect is shown in Fig. 4.73. The individual effect of D, B and M was found significant on the true protein of sliced turmeric (4 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.3). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

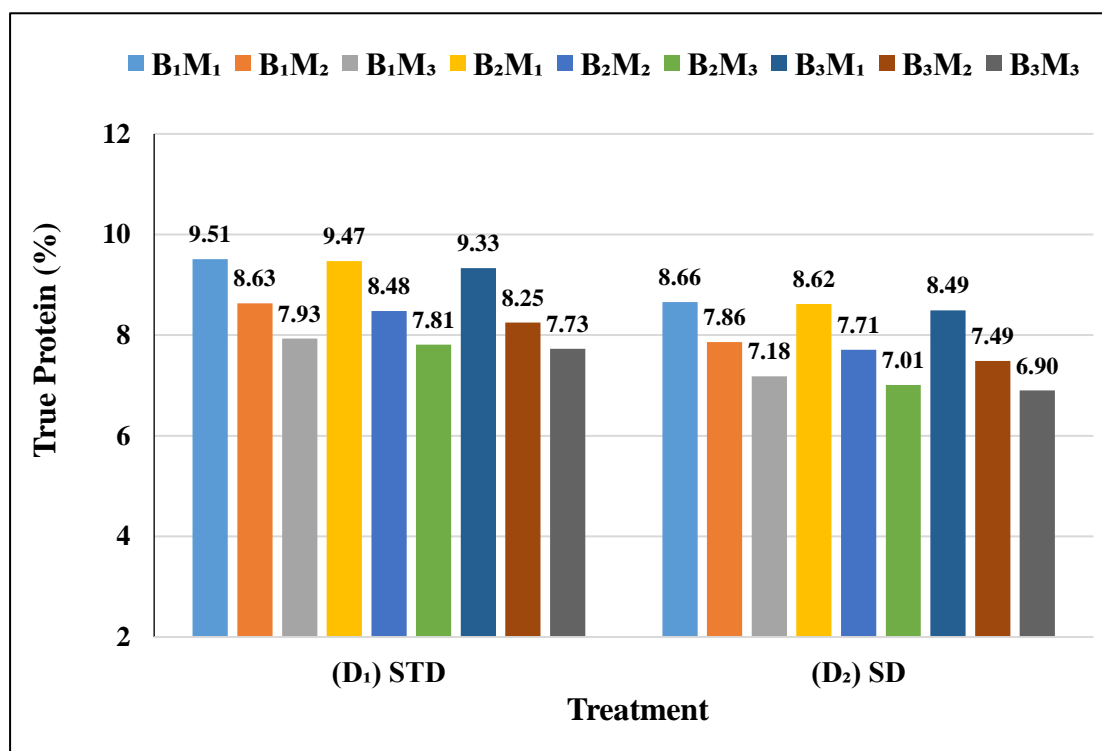


Fig. 4.73 Effect of different treatments on true protein of 4 mm turmeric slices

5) Effect of drying methods and sliced thickness (5 mm) on true protein

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.74) that true protein increased with solar tunnel drying methods. The highest true protein of 10.01% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest

true protein of 7.27% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.12) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the true protein of sliced turmeric. The true protein of solar tunnel drying D₁ (8.99%) was significantly higher than that of sun drying method D₂ (8.18%).

6) Effect of blanching temperature and slice thickness (5 mm) on true protein

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that true protein of sliced turmeric decreased with increase in blanching temperature. The highest true protein of 10.01% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest true protein of 7.27% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.12) also revealed that the effect of blanching temperature (B) was found significant. The true protein of B₁ (8.73%) was significantly higher than that of B₂ (8.60%) and B₃ (8.43%).

7) Effect of blanching time and slice thickness (5 mm) on true protein

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that true protein decreased with increase in blanching time. The highest true protein of 10.01% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest true protein of 7.27% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried). An increase in protein, lipid and carbohydrate contents content were observed after blanching (Gorinstein et al., 2005).

The analysed data (Table 4.12) also revealed that the significant effect of blanching time (M). The true protein of M₁ (9.49%) was significantly higher than that of M₂ (8.49%) and M₃ (7.77%).

8) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on true protein

The graphical presentation of the combined effect is shown in Fig. 4.74. The individual effect of D, B and M was found significant on the true protein of sliced turmeric (5 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.12). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

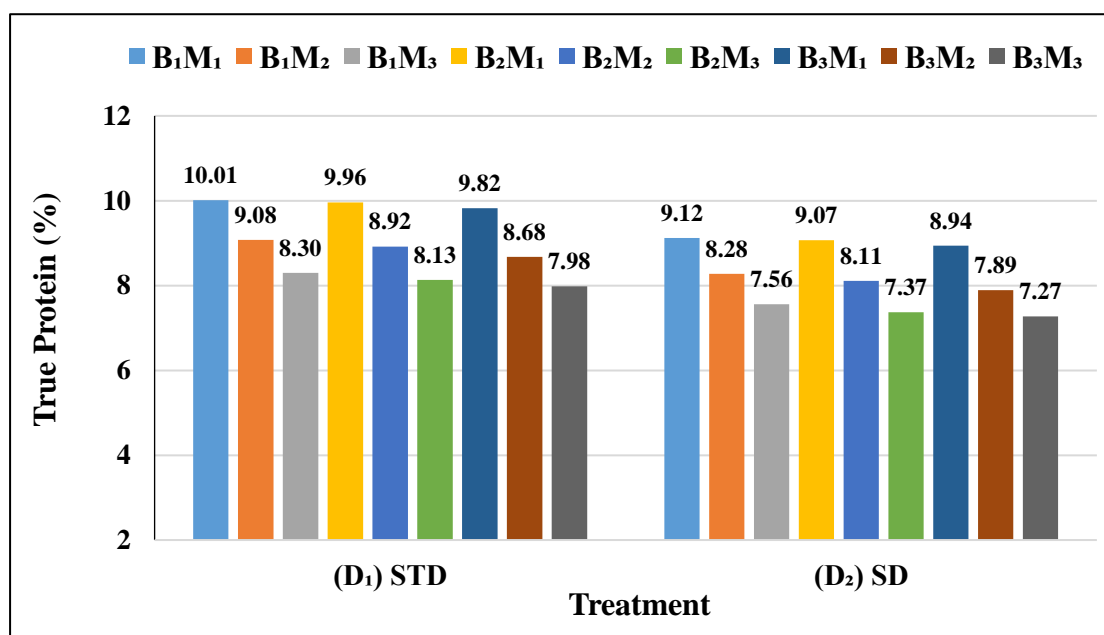


Fig. 4.74 Effect of different treatments on true protein of 5mm turmeric slices

9) Effect of drying methods and whole turmeric on true protein

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.75) that true protein increased with solar tunnel drying methods. The highest true protein of 9.07% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest true protein of 6.56% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.12) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the true protein of whole turmeric. The true protein of solar tunnel drying D₁ (8.34%) was significantly higher than that of sun drying method D₂ (7.38%).

10) Effect of blanching temperature and whole turmeric on true protein

The blanching of whole turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that true protein of turmeric decreased with increase in blanching temperature. The highest true protein of 9.07% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest true protein of 6.56% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.12) also revealed that the effect of blanching temperature (B) was found significant. The true protein of B₁ (8.02%) was significantly higher than that of B₂ (7.85%) and B₃ (7.72%).

11) Effect of blanching time and whole turmeric on true protein

The blanching of whole turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that true protein decreased with increase in blanching time. The highest true protein of 9.07% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest true protein of 6.56% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.12) also revealed that the significant effect of blanching time (M). The true protein of M₁ (8.48%) was significantly higher than that of M₂ (7.85%) and M₃ (7.25%).

High temperature and prolonged drying results in protein denaturation which accounts for the decrease in protein as slice thickness increased (Korese and Achaglinkame, 2022). However, protein decreased as slice thickness increased. This is because the whole turmeric took a longer time to dry as compared to the slice samples.

12) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on true protein

The graphical presentation of the combined effect is shown in Fig. 4.75. The individual effect of D, B and M was found significant on the true protein of whole turmeric. However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.12). It may be the inherent nature of the factors. When interactions are non-significant, it means that levels of one factor are consistent over various levels of another factor.

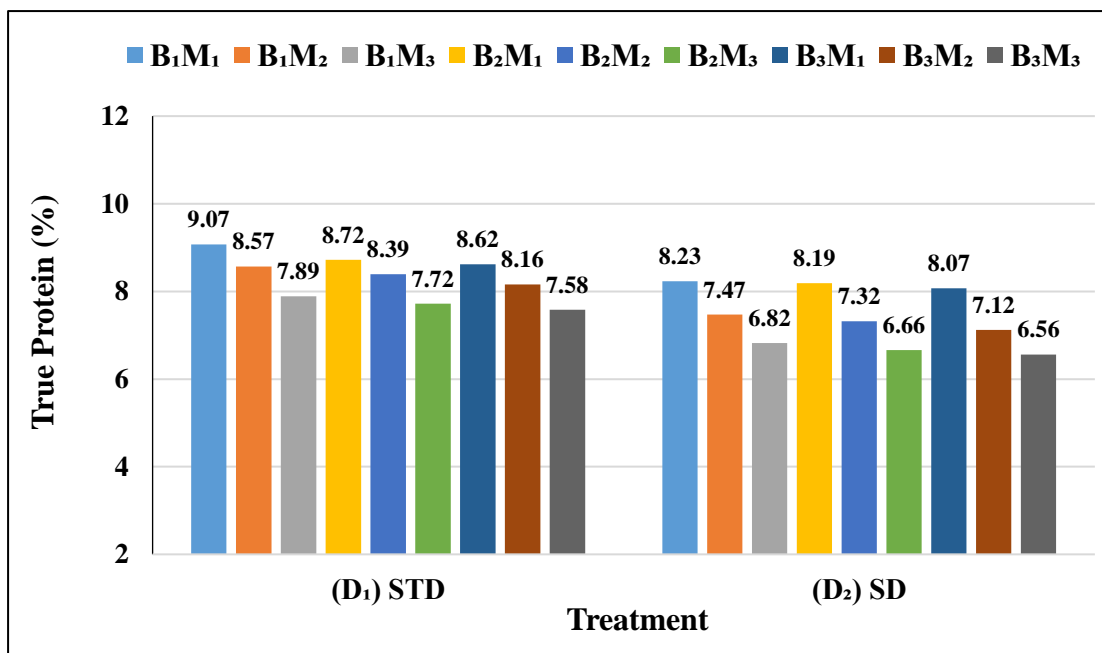


Fig. 4.75 Effect of different treatments on true protein of whole turmeric

4.8.1.4 Total oil content

4.8.1.4.1 Effect of pretreatments and drying methods on total oil content

The total oil content of sliced and whole turmeric influenced by blanching temperature, time and drying methods. The value of total oil at different drying methods (i.e., solar tunnel drying and sun drying), blanching temperature (70°C, 80°C and 90°C), and blanching time (15 min, 30 min and 45 min) are presented in Table 4.13. The mean values of total oil are presented in APPENDIX-H1 and APPENDIX-H2, respectively. Effects of these process variables on total oil of turmeric are discussed hereunder.

Table 4.13 Effect of different blanching temperatures and times on total oil of dried turmeric by different methods

| Sr. No. | Treatments | 4 mm | | 5 mm | | whole | |
|---------|-------------------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|----------------------|
| | | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD |
| 1 | B ₁ M ₁ | 4.61 | 4.01 | 4.70 | 4.10 | 4.90 | 4.27 |
| 2 | B ₁ M ₂ | 4.27 | 3.71 | 4.36 | 3.79 | 4.54 | 3.95 |
| 3 | B ₁ M ₃ | 3.48 | 3.02 | 3.55 | 3.09 | 3.70 | 3.22 |
| 4 | B ₂ M ₁ | 4.52 | 3.95 | 4.61 | 4.03 | 4.80 | 4.20 |
| 5 | B ₂ M ₂ | 4.10 | 3.56 | 4.18 | 3.63 | 4.36 | 3.78 |
| 6 | B ₂ M ₃ | 3.35 | 2.91 | 3.42 | 2.97 | 3.56 | 3.10 |
| 7 | B ₃ M ₁ | 4.42 | 3.84 | 4.51 | 3.92 | 4.69 | 4.08 |
| 8 | B ₃ M ₂ | 3.64 | 3.17 | 3.72 | 3.24 | 3.87 | 3.37 |
| 9 | B ₃ M ₃ | 3.01 | 2.73 | 3.07 | 2.78 | 3.20 | 2.90 |

Table 4.14 Effect of drying method, blanching temperatures and time on total oil of sliced and whole dried turmeric rhizomes

| Total Oil | | | |
|----------------------------------|------------|------------|--------------|
| Treatment | 4mm | 5mm | whole |
| Drying methods (D) | | | |
| D₁ (STD) | 3.93 | 4.01 | 4.18 |
| D₂ (SD) | 3.43 | 3.51 | 3.65 |
| S.Em.± | 0.03 | 0.03 | 0.05 |
| C.D. at 5 % | 0.08 | 0.09 | 0.16 |
| Blanching temperature (B) | | | |
| B₁ (70°C) | 3.85 | 3.93 | 4.09 |
| B₂ (80°C) | 3.73 | 3.81 | 3.97 |
| B₃ (90°C) | 3.47 | 3.54 | 3.69 |
| S.Em.± | 0.04 | 0.05 | 0.06 |
| C.D. at 5 % | 0.10 | 0.11 | 0.19 |
| Blanching time (M) | | | |
| M₁ (15 min.) | 4.22 | 4.31 | 4.49 |
| M₂ (30 min.) | 3.74 | 3.82 | 3.98 |
| M₃ (45 min.) | 3.08 | 3.15 | 3.28 |
| S.Em.± | 0.04 | 0.05 | 0.06 |
| C.D. at 5 % | 0.10 | 0.11 | 0.19 |
| C.V. % | 3.19 | 3.55 | 5.71 |
| D X B | | | |
| S.Em.± | 0.05 | 0.05 | 0.09 |
| C.D. at 5 % | NS | NS | NS |
| D X M | | | |
| S.Em.± | 0.05 | 0.05 | 0.09 |
| C.D. at 5 % | NS | NS | NS |
| B X M | | | |
| S.Em.± | 0.06 | 0.07 | 0.11 |
| C.D. at 5 % | 0.17 | 0.19 | 0.22 |
| D X B X M | | | |
| S.Em.± | 0.08 | 0.09 | 0.16 |
| C.D. at 5 % | NS | NS | NS |

1) Effect of drying methods and sliced thickness (4 mm) on total oil

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.76) that total oil increased with solar tunnel drying

methods. The highest total oil o 4.61% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total oil of 2.73% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.14) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the total oil of sliced turmeric. The total oil content of solar tunnel drying D₁ (3.93%) was significantly higher than that of sun drying method D₂ (3.43%).

2) Effect of blanching temperature and sliced thickness (4 mm) on total oil

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that total oil of sliced turmeric decreased with increase in blanching temperature. The highest total oil o 4.61% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total oil of 2.73% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.14) also revealed that the effect of blanching temperature (B) was found significant. The total oil content of B₁ (3.85%) was significantly higher than that of B₂ (3.73%) and B₃ (3.47%).

3) Effect of blanching time and slice thickness (4 mm) on total oil

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total oil decreased with increase in blanching time. The highest total oil o 4.61% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total oil of 2.73% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.14) also revealed that the significant effect of blanching time (M). The total oil content of M₁ (4.22%) was significantly higher than that of M₂ (3.74%) and M₃ (3.08%).

4) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total oil

The graphical presentation of the combined effect is shown in Fig. 4.76. The individual effect of D, B and M was found significant on the total oil of sliced turmeric (4 mm). However, the interaction between DxB, D \times M and D \times B \times M was non-significant except B \times M (Table 4.14). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

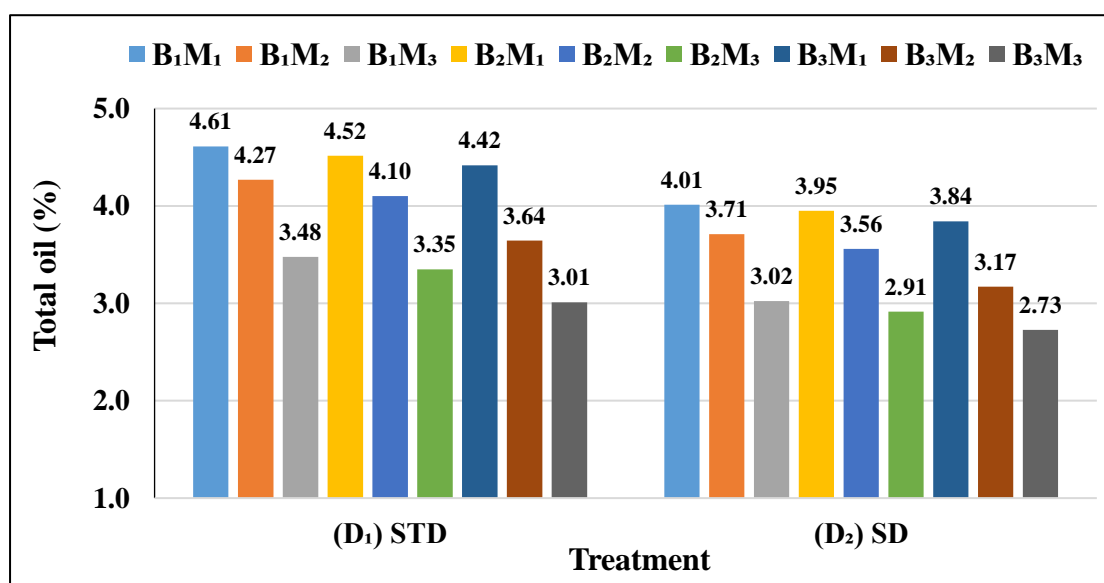


Fig. 4.76 Effect of different treatments on total oil of 4 mm turmeric slices

5) Effect of drying methods and sliced thickness (5 mm) on total oil

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.77) that total oil increased with solar tunnel drying methods. The highest total oil of 4.70% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total oil of 2.78% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried).

The analysed data (Table 4.14) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the total oil of sliced turmeric. The total oil content of solar tunnel drying D₁ (4.01%) was significantly higher than that of sun drying method D₂ (3.51%).

6) Effect of blanching temperature and slice thickness (5 mm) on total oil

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that total oil of sliced turmeric increased with decrease in blanching temperature. The highest total oil of 4.70% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total oil of 2.78% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried).

The analysed data (Table 4.14) also revealed that the effect of blanching temperature (B) was found significant. The total oil content of B₁ (3.93%) was significantly higher than that of B₂ (3.81%) and B₃ (3.54%).

7) Effect of blanching time and slice thickness (5 mm) on total oil

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total oil decreased with increase in blanching time. The highest total oil of 4.70% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total oil of 2.78% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried). The analysed data (Table 4.14) also revealed that the significant effect of blanching time (M). The total oil content of M₁ (4.31%) was significantly higher than that of M₂ (3.82%) and M₃ (3.54%).

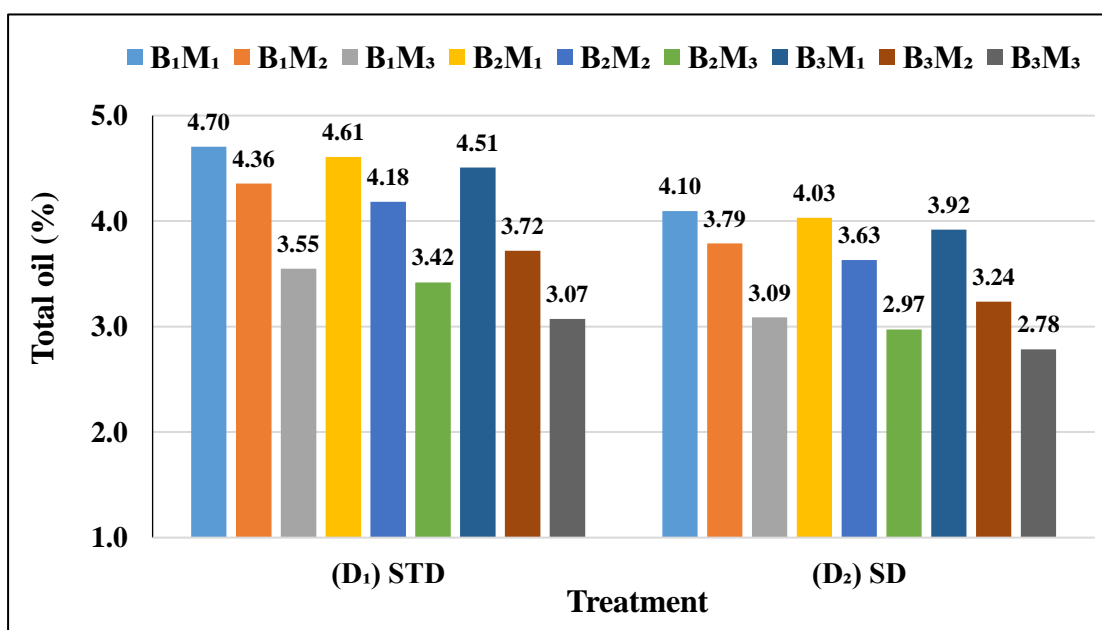


Fig. 4.77 Effect of different treatments on total oil of 5 mm turmeric slices

8) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total oil

The graphical presentation of the combined effect is shown in Fig. 4.77. The individual effect of D, B and M was found significant on the total oil of sliced turmeric (5 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.14). When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

9) Effect of drying methods and whole turmeric on total oil

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.78) that total oil increased with solar tunnel drying methods. The highest total oil of 4.90% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total oil of 2.90% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried).

The analysed data (Table 4.14) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the total oil of whole turmeric. The total oil content of solar tunnel drying D₁ (4.18%) was significantly higher than that of sun drying method D₂ (3.65%).

10) Effect of blanching temperature and whole turmeric on total oil

The blanching of whole turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that total oil of whole turmeric decreased with increase in blanching temperature. The highest total oil of 4.90% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total oil of 2.90% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried).

The analysed data (Table 4.14) also revealed that the effect of blanching temperature (B) was found significant. The total oil content of B₁ (4.09%) was significantly higher than that of B₂ (3.97%) and B₃ (3.69%).

11) Effect of blanching time and whole turmeric on total oil

The blanching of whole turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total

oil increased with decrease in blanching time. The highest total oil of 4.90% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest total oil of 2.90% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun-dried).

The analysed data (Table 4.14) also revealed that the significant effect of blanching time (M). The total oil content of M₁ (4.49%) was significantly higher than that of M₂ (3.97%) and M₃ (3.69%).

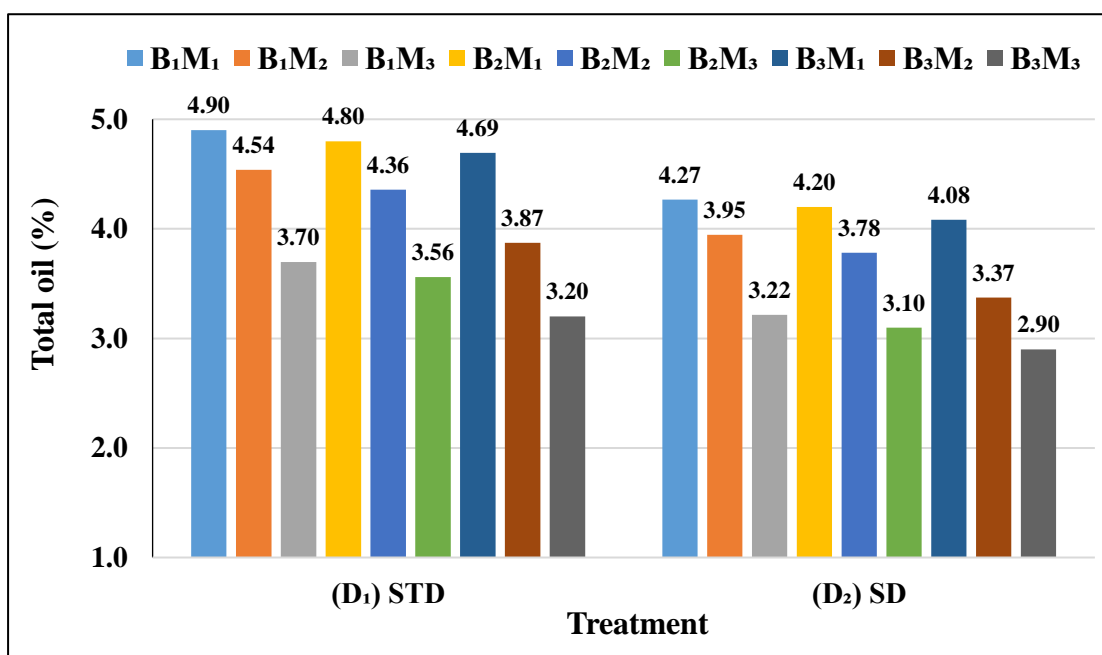


Fig. 4.78 Effect of different treatments on total oil of whole turmeric

12) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total oil

The graphical presentation of the combined effect is shown in Fig. 4.78. The individual effect of D, B and M was found significant on the total oil of whole turmeric. However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.14). It may be the inherent nature of the factors. When interactions are non-significant, it means that levels of one factor are consistent over various levels of another factor.

4.8.1.5 Total ash content

4.8.1.5.1 Effect of pretreatments and drying methods on total ash

The total ash of sliced and whole turmeric influenced by blanching temperature, time and drying methods. The value of total ash at different drying methods (i.e., solar tunnel drying and sun drying), blanching temperature (70°C, 80°C and 90°C), and blanching time (15 min, 30 min and 45 min) are presented in Table 4.15. The mean values of total ash are presented in APPENDIX-H1 and APPENDIX-H2, respectively. Effects of these process variables on total ash of turmeric are discussed hereunder.

1) Effect of drying methods and sliced thickness (4 mm) on total ash

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.79) that total ash increased with solar tunnel drying methods. The highest total ash of 7.42% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total ash of 5.79% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.16) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the total ash of sliced turmeric. The total ash content of solar tunnel drying D₁ (6.83%) was significantly higher than that of sun drying method D₂ (6.22%).

Table 4.15 Effect of different blanching temperatures and times on total ash of dried turmeric by different methods

| Sr. No. | Treatments | 4 mm | | 5 mm | | whole | |
|---------|-------------------------------|--------------------------|-------------------------|--------------------------|-------------------------|--------------------------|-------------------------|
| | | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD |
| 1 | B ₁ M ₁ | 7.42 | 6.75 | 8.09 | 7.36 | 8.57 | 7.80 |
| 2 | B ₁ M ₂ | 6.98 | 6.35 | 7.24 | 6.59 | 8.21 | 7.47 |
| 3 | B ₁ M ₃ | 6.56 | 5.97 | 6.85 | 6.23 | 7.58 | 6.90 |
| 4 | B ₂ M ₁ | 7.07 | 6.43 | 7.77 | 7.07 | 8.49 | 7.73 |
| 5 | B ₂ M ₂ | 6.87 | 6.25 | 7.11 | 6.47 | 7.91 | 7.20 |
| 6 | B ₂ M ₃ | 6.52 | 5.93 | 6.79 | 6.18 | 6.66 | 6.06 |
| 7 | B ₃ M ₁ | 7.01 | 6.38 | 7.31 | 6.65 | 8.37 | 7.62 |
| 8 | B ₃ M ₂ | 6.72 | 6.12 | 6.93 | 6.31 | 7.85 | 7.16 |
| 9 | B ₃ M ₃ | 6.36 | 5.79 | 6.40 | 5.82 | 6.46 | 5.88 |

Table 4.16 Effect of drying method, blanching temperatures and time on total ash of sliced and whole dried turmeric rhizomes

| Total Ash | | | |
|----------------------------------|------------|------------|--------------|
| Treatment | 4mm | 5mm | whole |
| Drying methods (D) | | | |
| D₁ (STD) | 6.83 | 7.17 | 7.79 |
| D₂ (SD) | 6.22 | 6.52 | 7.09 |
| S.Em.± | 0.06 | 0.07 | 0.07 |
| C.D. at 5 % | 0.18 | 0.21 | 0.22 |
| Blanching temperature (B) | | | |
| B₁ (70°C) | 6.67 | 7.06 | 7.75 |
| B₂ (80°C) | 6.51 | 6.90 | 7.34 |
| B₃ (90°C) | 6.40 | 6.57 | 7.22 |
| S.Em.± | 0.07 | 0.09 | 0.09 |
| C.D. at 5 % | NS | 0.26 | 0.31 |
| Blanching time (M) | | | |
| M₁ (15 min.) | 6.84 | 7.38 | 8.10 |
| M₂ (30 min.) | 6.55 | 6.77 | 7.63 |
| M₃ (45 min.) | 6.19 | 6.38 | 6.59 |
| S.Em.± | 0.07 | 0.09 | 0.09 |
| C.D. at 5 % | 0.22 | 0.26 | 0.31 |
| C.V. % | 3.95 | 4.36 | 4.27 |
| D X B | | | |
| S.Em.± | 0.11 | 0.12 | 0.17 |
| C.D. at 5 % | NS | NS | NS |
| D X M | | | |
| S.Em.± | 0.11 | 0.12 | 0.17 |
| C.D. at 5 % | NS | NS | NS |
| B X M | | | |
| S.Em.± | 0.13 | 0.15 | 0.16 |
| C.D. at 5 % | 0.07 | 0.11 | 0.21 |
| D X B X M | | | |
| S.Em.± | 0.18 | 0.21 | 0.22 |
| C.D. at 5 % | NS | NS | NS |

2) Effect of blanching temperature and sliced thickness (4 mm) on total ash

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that total ash of

sliced turmeric decreased with increase in blanching temperature. The highest total ash of 7.42% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total ash of 5.79% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.16) also revealed that the effect of blanching temperature (B) was found significant. The total ash content of B₁ (6.67%) was significantly higher than that of B₂ (6.51%) and B₃ (6.40%).

3) Effect of blanching time and slice thickness (4 mm) on total ash

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total ash decreased with increase in blanching time. The highest total ash of 7.42% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total ash of 5.79% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried). The analysed data (Table 4.16) also revealed that the significant effect of blanching time (M). The total ash content of M₁ (6.84%) was significantly higher than that of M₂ (6.55%) and M₃ (6.19%).

Ezeocha and Ojmelukwe (2012) reported that the boiling significantly reduced the ash content resulting in 29.91% loss in the ash content for yam crop. The significant reduction in ash content of the tubers with increased boiling period is in agreement with the results of Onu and Okongwu (2006). The observed decrease in ash content after cooking implies that the potential ability of these tubers to supply essential minerals has been reduced.

4) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total ash

The graphical presentation of the combined effect is shown in Fig. 4.79. The individual effect of D, B and M was found significant on the total ash of sliced turmeric (4 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.16). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

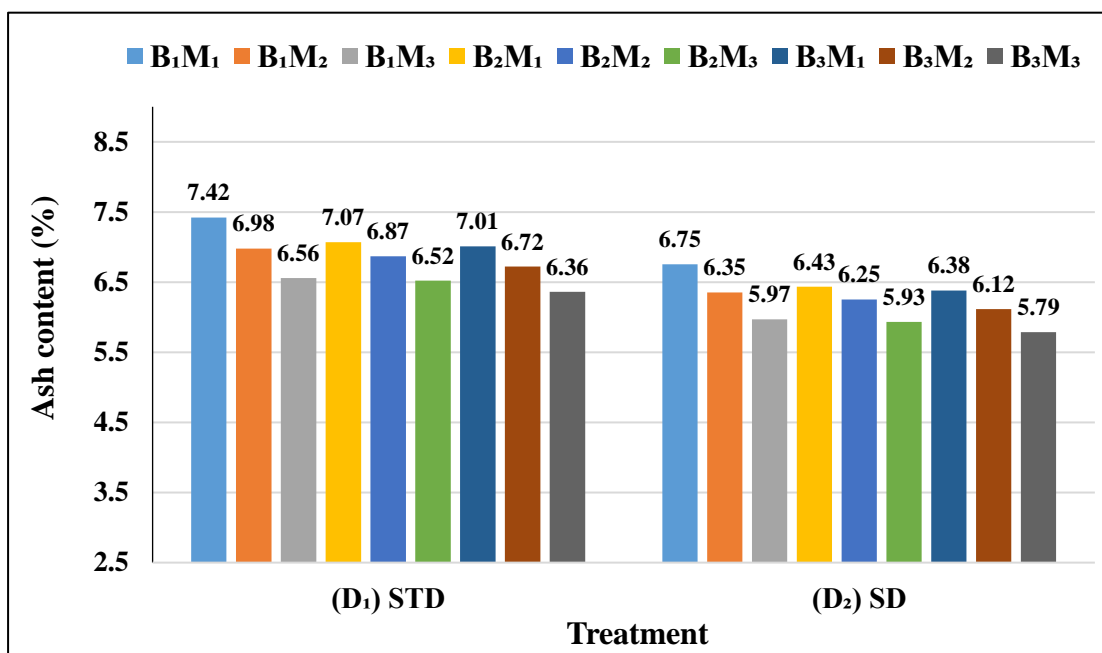


Fig. 4.79 Effect of different treatments on total ash of 4 mm turmeric slices

5) Effect of drying methods and sliced thickness (5 mm) on total ash

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.80) that total ash increased with solar tunnel drying methods. The highest total ash of 8.09% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total ash of 5.82% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.16) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the total ash of sliced turmeric. The total ash of solar tunnel drying D₁ (7.17%) was significantly higher than that of sun drying method D₂ (6.52%).

6) Effect of blanching temperature and slice thickness (5 mm) on total ash

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that total ash of sliced turmeric decreased with increase in blanching temperature. The highest total ash of 8.09% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total ash of 5.82% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.16) also revealed that the effect of blanching temperature (B) was found significant. The total ash of B₁ (7.06%) was significantly higher than that of B₂ (6.90%) and B₃ (6.57%).

7) Effect of blanching time and slice thickness (5 mm) on total ash

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total ash decreased with increase in blanching time. The highest total ash of 8.09% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total ash of 5.82% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The overall outcome of this experiment indicated that the amounts of carbon containing compounds in the rhizomes are affected by temperature magnitudes and duration of stay on boiling. Higher temperature levels for longer boiling durations organic materials vanishing (Zerihun *et al.*, 2017).

The analysed data (Table 4.16) also revealed that the significant effect of blanching time (M). The total ash of M₁ (7.38%) was significantly higher than that of M₂ (6.77%) and M₃ (6.38%).

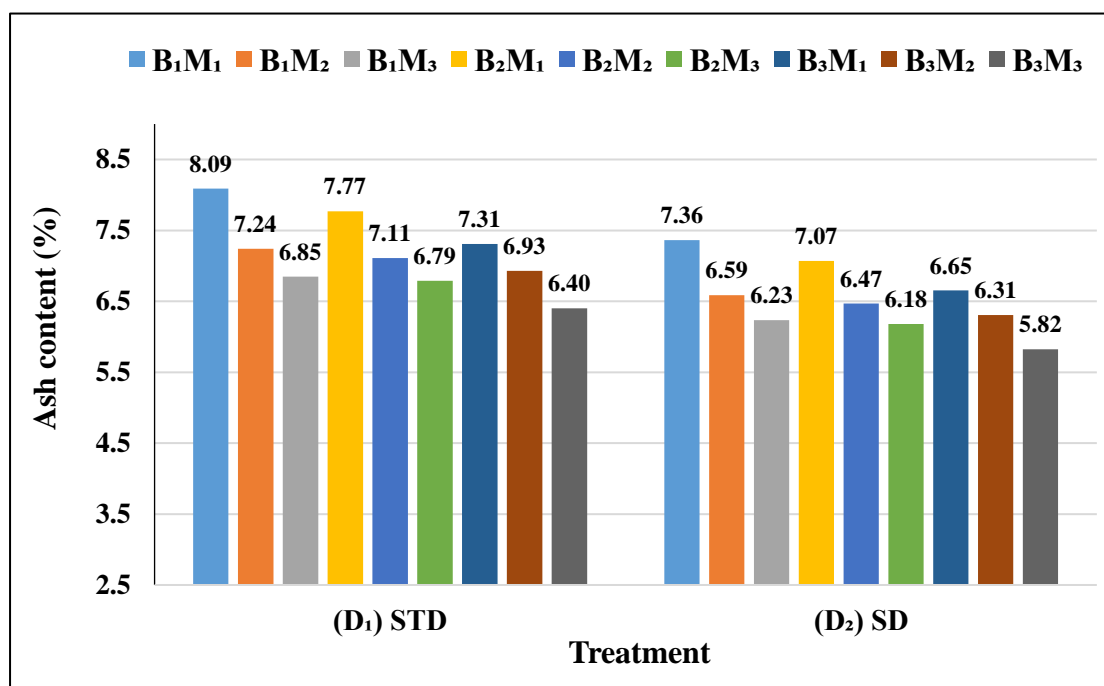


Fig. 4.80 Effect of different treatments on total ash of 5 mm turmeric slices

8) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total ash

The graphical presentation of the combined effect is shown in Fig. 4.80. The individual effect of D, B and M was found significant on the total ash of sliced turmeric (5 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.16). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

9) Effect of drying methods and whole turmeric on total ash

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.81) that total ash increased with solar tunnel drying methods. The highest total ash of 8.57% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total ash of 5.88% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.16) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the total ash of whole turmeric. The total ash of solar tunnel drying D₁ (7.79%) was significantly higher than that of sun drying method D₂ (7.09%).

10) Effect of blanching temperature and whole turmeric on total ash

The blanching of whole turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. The graphical presentation of the effect of blanching temperature on total ash of whole turmeric is shown in Fig. 4.115. The highest total ash of 8.57% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total ash of 5.88% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.16) also revealed that the effect of blanching temperature (B) was found significant. The total ash of B₁ (7.75%) was significantly higher than that of B₂ (7.34%) and B₃ (7.22%).

11) Effect of blanching time and whole turmeric on total ash

The blanching of whole turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total ash decreased with increase in blanching time. The highest total ash of 8.57% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total ash of 5.88% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

Ezeocha and Ojmelukwe (2012) reported that the boiling significantly reduced the ash content resulting in 29.91% loss in the ash content for yam crop. The significant reduction in ash content of the tubers with increased boiling period is in agreement with the results of Onu and Okongwu (2006). The observed decrease in ash content after cooking implies that the potential ability of these tubers to supply essential minerals has been reduced.

The analysed data (Table 4.16) also revealed that the significant effect of blanching time (M). The total ash of M₁ (8.10%) was significantly higher than that of M₂ (7.63%) and M₃ (6.59%).

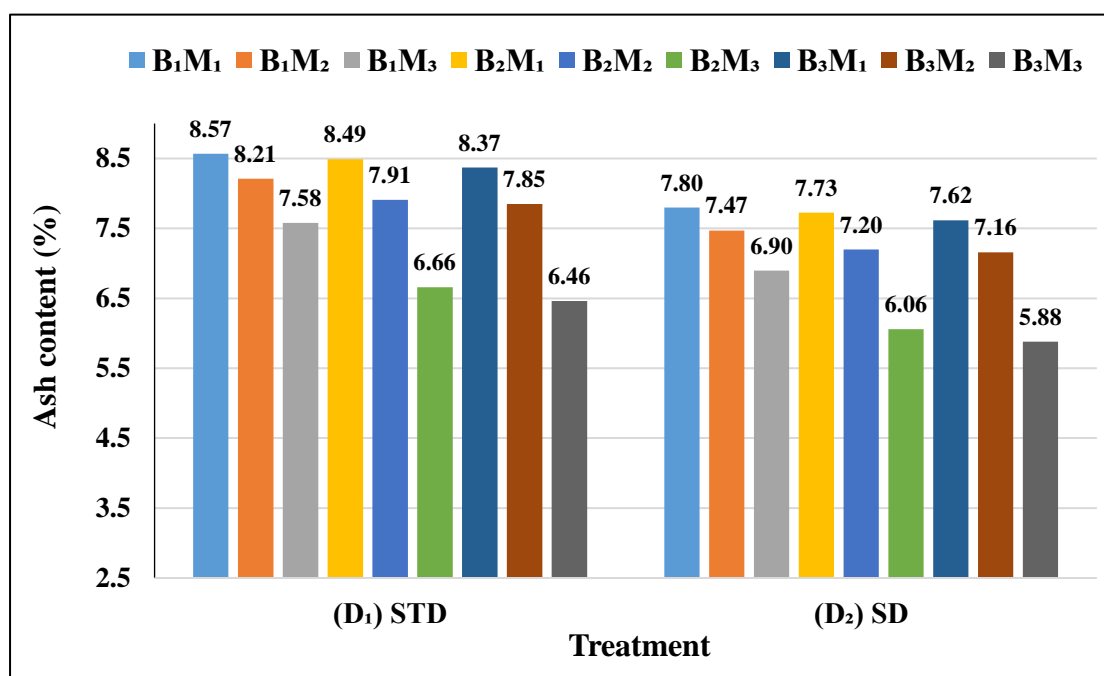


Fig. 4.81 Effect of different treatments on total ash of whole turmeric

12) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total ash

The graphical presentation of the combined effect is shown in Fig. 4.81. The individual effect of D, B and M was found significant on the total ash of whole turmeric. However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.16). It may be the inherent nature of the factors. When interactions are non-significant, it means that levels of one factor are consistent over various levels of another factor.

4.8.1.6 Curcumin content

4.8.1.6.1 Effect of pretreatments and drying methods on curcumin content

The curcumin content of sliced and whole turmeric influenced by blanching temperature, time and drying methods. The value of curcumin at different drying methods (i.e., solar tunnel drying and sun drying), blanching temperature (70°C, 80°C and 90°C), and blanching time (15 min, 30 min and 45 min) are presented in Table 4.17. The mean values of curcumin are presented in APPENDIX-H1 and APPENDIX-H2, respectively.

Table 4.17 Effect of blanching temperatures and times on curcumin content of dried turmeric by different methods

| Sr. No. | Treatments | 4 mm | | 5 mm | | whole | |
|---------|-------------------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|----------------------|
| | | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD |
| 1 | B ₁ M ₁ | 4.00 | 3.70 | 4.08 | 3.77 | 4.18 | 3.91 |
| 2 | B ₁ M ₂ | 3.26 | 2.99 | 3.36 | 3.08 | 4.09 | 3.78 |
| 3 | B ₁ M ₃ | 2.90 | 2.72 | 3.01 | 2.82 | 3.62 | 3.26 |
| 4 | B ₂ M ₁ | 3.58 | 3.25 | 3.65 | 3.32 | 4.15 | 3.89 |
| 5 | B ₂ M ₂ | 3.16 | 2.95 | 3.26 | 3.04 | 4.01 | 3.65 |
| 6 | B ₂ M ₃ | 2.85 | 2.59 | 2.95 | 2.69 | 2.69 | 2.47 |
| 7 | B ₃ M ₁ | 3.32 | 3.11 | 3.39 | 3.17 | 4.11 | 3.88 |
| 8 | B ₃ M ₂ | 3.02 | 2.76 | 3.11 | 2.84 | 3.85 | 3.51 |
| 9 | B ₃ M ₃ | 2.17 | 1.99 | 2.25 | 2.06 | 2.37 | 2.20 |

Table 4.18 Effect of drying method, blanching temperatures and time on curcumin content of sliced and whole dried turmeric rhizomes

| Curcumin content | | | |
|----------------------------------|------------|------------|--------------|
| Treatment | 4mm | 5mm | whole |
| Drying methods (D) | | | |
| D₁ (STD) | 3.15 | 3.24 | 3.67 |
| D₂ (SD) | 2.89 | 2.98 | 3.39 |
| S.Em.± | 0.03 | 0.03 | 0.04 |
| C.D. at 5 % | 0.08 | 0.08 | 0.11 |
| Blanching temperature (B) | | | |
| B₁ (70°C) | 3.26 | 3.35 | 3.81 |
| B₂ (80°C) | 3.08 | 3.17 | 3.47 |
| B₃ (90°C) | 2.73 | 2.80 | 3.32 |
| S.Em.± | 0.03 | 0.03 | 0.05 |
| C.D. at 5 % | 0.09 | 0.10 | 0.13 |
| Blanching time (M) | | | |
| M₁ (15 min.) | 3.49 | 3.56 | 4.02 |
| M₂ (30 min.) | 3.04 | 3.13 | 3.82 |
| M₃ (45 min.) | 2.54 | 2.63 | 2.77 |
| S.Em.± | 0.03 | 0.03 | 0.05 |
| C.D. at 5 % | 0.09 | 0.10 | 0.13 |
| C.V. % | 3.59 | 3.68 | 4.44 |
| D X B | | | |
| S.Em.± | 0.04 | 0.05 | 0.06 |
| C.D. at 5 % | NS | NS | NS |
| D X M | | | |
| S.Em.± | 0.04 | 0.05 | 0.06 |
| C.D. at 5 % | NS | NS | NS |
| B X M | | | |
| S.Em.± | 0.05 | 0.06 | 0.08 |
| C.D. at 5 % | 0.16 | 0.17 | 0.23 |
| D X B X M | | | |
| S.Em.± | 0.08 | 0.08 | 0.11 |
| C.D. at 5 % | NS | NS | NS |

1) Effect of drying methods and sliced thickness (4 mm) on curcumin

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.82) that curcumin increased with solar tunnel

drying methods. The highest curcumin of 4.00% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest curcumin of 1.99% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.18) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the curcumin of sliced turmeric. The curcumin content of solar tunnel drying D₁ (3.15%) was significantly higher than that of sun drying method D₂ (2.89%).

2) Effect of blanching temperature and sliced thickness (4 mm) on curcumin

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that curcumin of sliced turmeric increased with decrease in blanching temperature. The highest curcumin of 4.00% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest curcumin of 1.99% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.18) also revealed that the effect of blanching temperature (B) was found significant. The curcumin content of B₁ (3.26%) was significantly higher than that of B₂ (3.08%) and B₃ (2.73%).

3) Effect of blanching time and slice thickness (4 mm) on curcumin

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that curcumin decreased with increase in blanching time. The highest curcumin of 4.00% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest curcumin of 1.99% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The lowest percentage of *Curcuma* was recorded for sliced sun-dried sample which was boiled for the longest time, 60 minutes. The degradation of curcuminoids of turmeric due to extended blanching time, sliced samples dried in the open sun light which caused loss of curcumin constituents. Whole turmeric and polytunnel drying of rhizomes help to maintain curcumin yield for boiling times of 15 to 45 minutes. This result is in line with the work of (Shinde *et al.*, 2011) who found decreasing value of

curcumin content when the boiling time increased and reported that boiling turmeric for 15 minutes yielded curcumin contents is highest.

The analysed data (Table 4.18) also revealed that the significant effect of blanching time (M). The curcumin content of M₁ (3.49%) was significantly higher than that of M₂ (3.04%) and M₃ (2.54%).

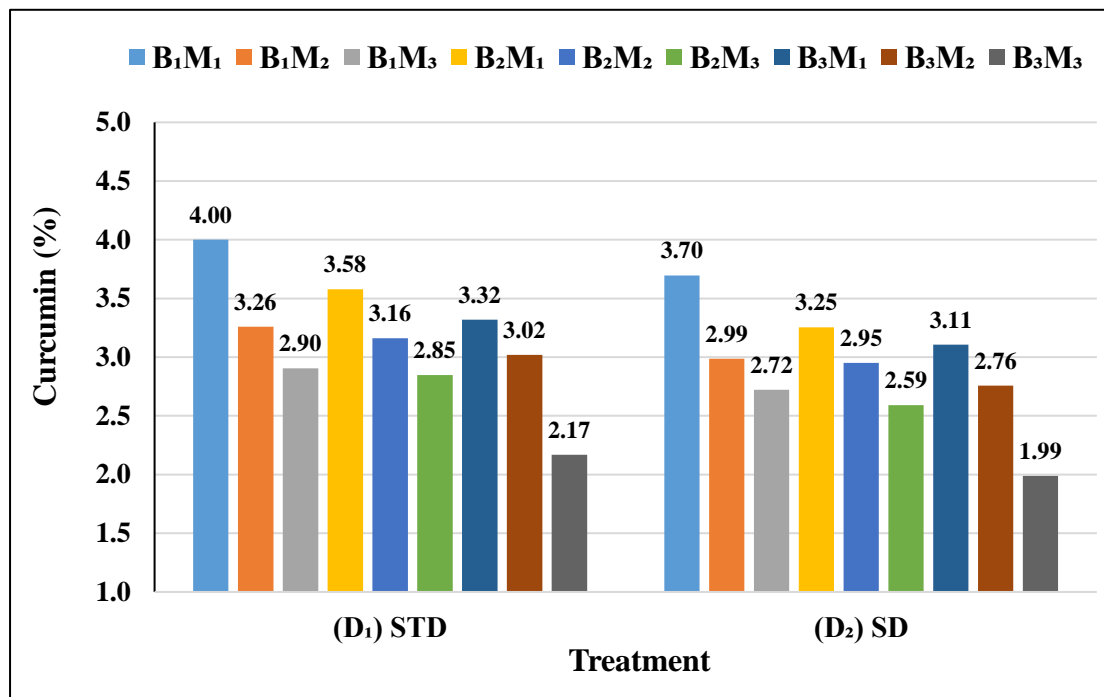


Fig. 4.82 Effect of different treatments on curcumin content of 4 mm slices turmeric

4) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on curcumin

The graphical presentation of the combined effect is shown in Fig. 4.82. The individual effect of D, B and M was found significant on the curcumin of sliced turmeric (4 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.18). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

5) Effect of drying methods and sliced thickness (5 mm) on curcumin

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.83) that curcumin increased with solar tunnel

drying methods. The highest curcumin of 4.08% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest curcumin of 2.06% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.18) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the curcumin of sliced turmeric. The curcumin content of solar tunnel drying D₁ (3.24%) was significantly higher than that of sun drying method D₂ (2.98%).

6) Effect of blanching temperature and slice thickness (5 mm) on curcumin

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that curcumin of sliced turmeric increased with decrease in blanching temperature. The highest curcumin of 4.08% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest curcumin of 2.06% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.18) also revealed that the effect of blanching temperature (B) was found significant. The curcumin content of B₁ (3.35%) was significantly higher than that of B₂ (3.17%) and B₃ (2.80%).

7) Effect of blanching time and slice thickness (5 mm) on curcumin

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that curcumin decreased with increase in blanching time.

The highest curcumin of 4.08% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest curcumin of 2.06% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The curcumin content hovered higher for unsliced turmeric and lower for sliced turmeric. The lower value of sliced turmeric due to loss of curcumin during drying of sliced of turmeric (Jayashree *et al.*, 2014). This may be due to the reason that hydro-boiling pretreatment and longer drying time. The volatile oil content of unsliced

turmeric was more as compared to sliced turmeric. The curcumin content higher for low time interval of blanching (Kurhekar *et al.*, 2015).

The analysed data (Table 4.18) also revealed that the significant effect of blanching time (M). The curcumin content of M₁ (3.56%) was significantly higher than that of M₂ (3.13%) and M₃ (2.63%).

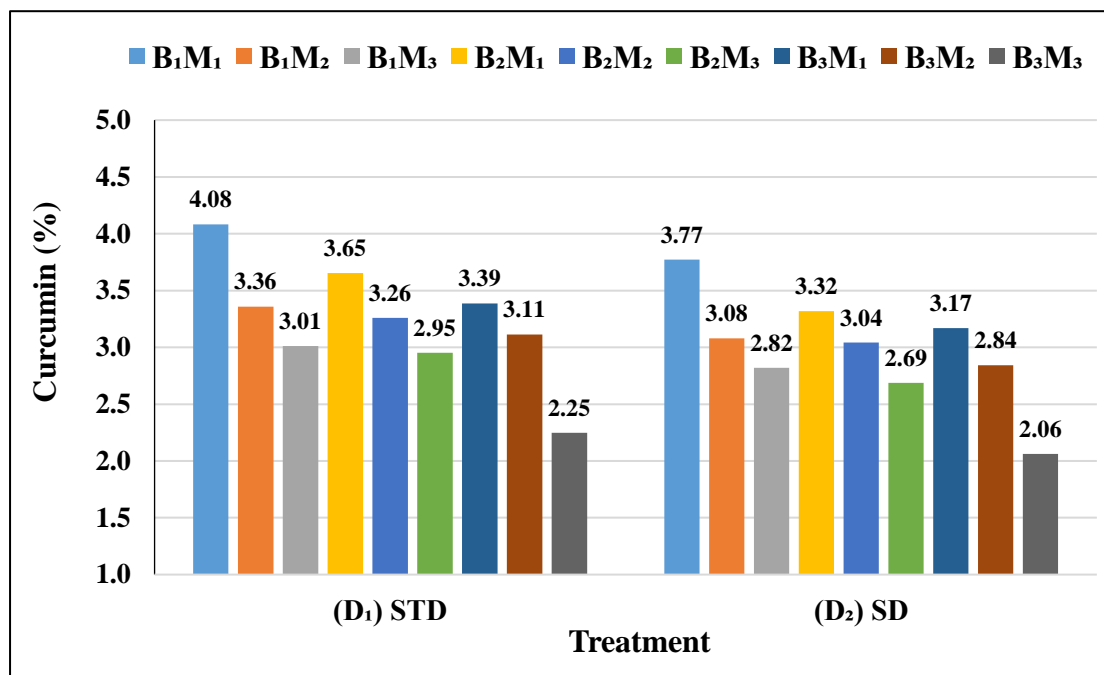


Fig. 4.83 Effect of different treatments on curcumin content of 5 mm turmeric slices

8) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on curcumin

The graphical presentation of the combined effect is shown in Fig. 4.83. The individual effect of D, B and M was found significant on the curcumin of sliced turmeric (5 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.18). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

9) Effect of drying methods and whole turmeric on curcumin

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.84) that curcumin increased with solar tunnel

drying methods. The highest curcumin of 4.18% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest curcumin of 2.20% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.18) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the curcumin of whole turmeric. The curcumin content of solar tunnel drying D₁ (3.67%) was significantly higher than that of sun drying method D₂ (3.39%).

10) Effect of blanching temperature and whole turmeric on curcumin

The blanching of turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that curcumin of turmeric decreased with increase in blanching temperature. The highest curcumin of 4.18% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest curcumin of 2.20% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.18) also revealed that the effect of blanching temperature (B) was found significant. The curcumin content of B₁ (3.81%) was significantly higher than that of B₂ (3.47%) and B₃ (3.32%).

11) Effect of blanching time and whole turmeric on curcumin

The blanching of whole turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that curcumin decreased with increase in blanching time. The highest curcumin of 4.18% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and the lowest curcumin of 2.20% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The lowest percentage of *Curcuma* was recorded for sliced sun-dried sample which was boiled for the longest time, 60 minutes. The degradation of curcuminoids of turmeric due to extended blanching time, sliced samples dried in the open sun light which caused loss of curcumin constituents. Whole turmeric and polytunnel drying of rhizomes help to maintain curcumin yield for boiling times of 15 to 45 minutes. This result is in line with the work of (Shinde *et al.*, 2011) who found decreasing value of

curcumin content when the boiling time increased and reported that boiling turmeric for 15 minutes yielded curcumin contents is highest.

The analysed data (Table 4.18) also revealed that the significant effect of blanching time (M). The curcumin content of M₁ (4.02%) was significantly higher than that of M₂ (3.82%) and M₃ (2.77%).

12) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on curcumin

The graphical presentation of the combined effect is shown in Fig. 4.84. The individual effect of D, B and M was found significant on the curcumin of whole turmeric. However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.18). It may be the inherent nature of the factors. When interactions are non-significant, it means that levels of one factor are consistent over various levels of another factor.

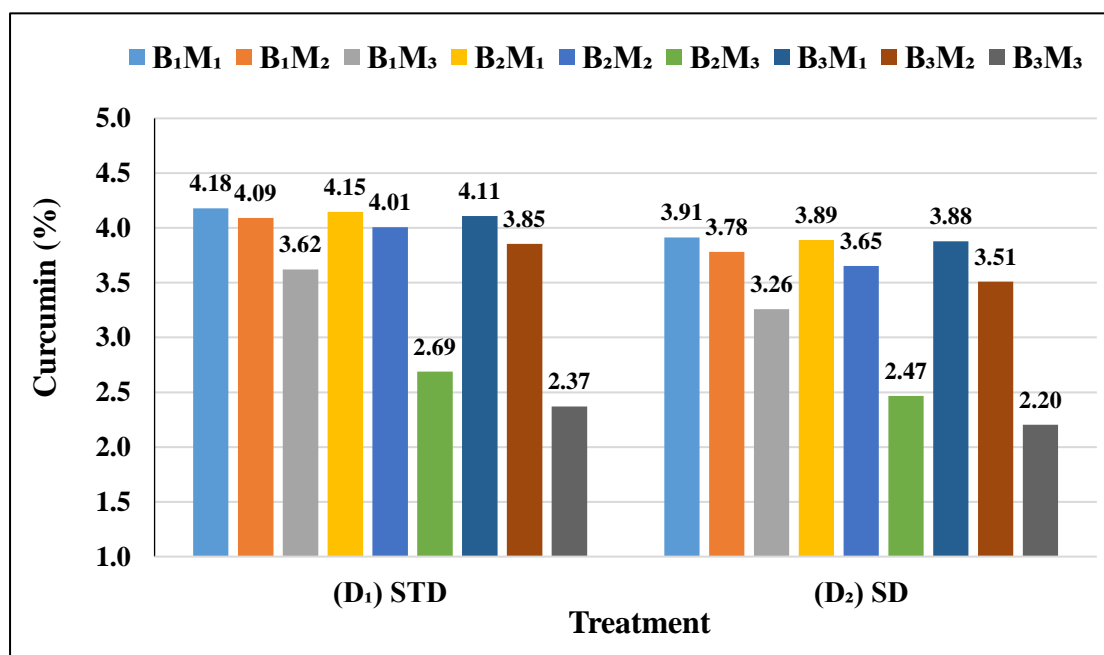


Fig. 4.84 Effect of different treatments on curcumin content of whole turmeric

4.8.1.7 Volatile oil content

4.8.1.7.1 Effect of pretreatments and drying methods on volatile oil content

The volatile oil content of sliced and whole turmeric influenced by blanching temperature, time and drying methods. The value of volatile oil at different drying

methods (i.e., solar tunnel drying and sun drying), blanching temperature (70°C, 80°C and 90°C), and blanching time (15 min, 30 min and 45 min) are presented in Table 4.19. The mean values of volatile oil are presented in APPENDIX-H1 and APPENDIX-H2, respectively. Effects of these process variables on volatile oil of turmeric are discussed hereunder.

Table 4.19 Effect of blanching temperatures and times on volatile oil of dried turmeric by different methods

| Sr. No. | Treatments | 4 mm | | 5 mm | | whole | |
|---------|-------------------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|----------------------|
| | | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD |
| 1 | B ₁ M ₁ | 3.76 | 3.33 | 3.84 | 3.40 | 4.00 | 3.55 |
| 2 | B ₁ M ₂ | 3.49 | 3.15 | 3.60 | 3.25 | 3.80 | 3.25 |
| 3 | B ₁ M ₃ | 3.29 | 2.95 | 3.39 | 3.04 | 3.60 | 3.15 |
| 4 | B ₂ M ₁ | 3.72 | 3.28 | 3.80 | 3.35 | 3.92 | 3.49 |
| 5 | B ₂ M ₂ | 3.30 | 2.96 | 3.40 | 3.15 | 3.75 | 3.22 |
| 6 | B ₂ M ₃ | 3.10 | 2.87 | 3.20 | 2.96 | 3.40 | 3.10 |
| 7 | B ₃ M ₁ | 3.53 | 3.18 | 3.60 | 3.25 | 3.80 | 3.40 |
| 8 | B ₃ M ₂ | 3.20 | 2.80 | 3.30 | 3.10 | 3.59 | 3.21 |
| 9 | B ₃ M ₃ | 2.91 | 2.62 | 3.00 | 2.70 | 3.29 | 3.04 |

1) Effect of drying methods and sliced thickness (4 mm) on volatile oil

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.85) that volatile oil increased with solar tunnel drying methods. The highest volatile oil of 3.76% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest volatile oil of 2.62% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.20) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the volatile oil of sliced turmeric. The volatile oil content of solar tunnel drying D₁ (3.38%) was significantly higher than that of sun drying method D₂ (3.04%).

Table 4.20 Effect of drying method, blanching temperatures and time on volatile oil of sliced and whole dried turmeric rhizomes

| Volatile Oil | | | |
|----------------------------------|------------|------------|--------------|
| Treatment | 4mm | 5mm | whole |
| Drying methods (D) | | | |
| D₁ (STD) | 3.38 | 3.47 | 3.67 |
| D₂ (SD) | 3.04 | 3.13 | 3.26 |
| S.Em.± | 0.02 | 0.03 | 0.05 |
| C.D. at 5 % | 0.07 | 0.08 | 0.14 |
| Blanching temperature (B) | | | |
| B₁ (70°C) | 3.33 | 3.42 | 3.50 |
| B₂ (80°C) | 3.21 | 3.31 | 3.49 |
| B₃ (90°C) | 3.09 | 3.17 | 3.41 |
| S.Em.± | 0.03 | 0.03 | 0.06 |
| C.D. at 5 % | 0.09 | 0.10 | 0.17 |
| Blanching time (M) | | | |
| M₁ (15 min.) | 3.47 | 3.54 | 3.70 |
| M₂ (30 min.) | 3.20 | 3.31 | 3.47 |
| M₃ (45 min.) | 2.96 | 3.05 | 3.22 |
| S.Em.± | 0.03 | 0.03 | 0.06 |
| C.D. at 5 % | 0.09 | 0.10 | 0.17 |
| C.V. % | 3.18 | 3.55 | 5.68 |
| D X B | | | |
| S.Em.± | 0.04 | 0.05 | 0.08 |
| C.D. at 5 % | NS | NS | NS |
| D X M | | | |
| S.Em.± | 0.04 | 0.05 | 0.08 |
| C.D. at 5 % | NS | NS | NS |
| B X M | | | |
| S.Em.± | 0.05 | 0.06 | 0.10 |
| C.D. at 5 % | 0.13 | 0.15 | 0.25 |
| D X B X M | | | |
| S.Em.± | 0.07 | 0.08 | 0.14 |
| C.D. at 5 % | NS | NS | NS |

2) Effect of blanching temperature and sliced thickness (4 mm) on volatile oil

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that volatile oil of

sliced turmeric increased with decrease in blanching temperature. The highest volatile oil of 3.76% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest volatile oil of 2.62% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.20) also revealed that the effect of blanching temperature (B) was found significant. The volatile oil content of B₁ (3.33%) was significantly higher than that of B₂ (3.21%) and B₃ (3.09%).

3) Effect of blanching time and slice thickness (4 mm) on volatile oil

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that volatile oil decreased with increase in blanching time. The highest volatile oil of 3.76% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest volatile oil of 2.62% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The essential oils content hovered higher for unsliced turmeric and lower for sliced turmeric. The lower value of sliced turmeric due to loss of during drying of sliced turmeric (Jayashree *et al.*, 2014). This may be due to the reason that hydro-boiling pretreatment and longer drying time. The volatile oil content of unsliced turmeric was more as compared to sliced turmeric.

The analysed data (Table 4.20) also revealed that the significant effect of blanching time (M). The volatile oil content of M₁ (3.47%) was significantly higher than that of M₂ (3.20%) and M₃ (2.96%).

4) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on volatile oil

The graphical presentation of the combined effect is shown in Fig. 4.85. The individual effect of D, B and M was found significant on the volatile oil of sliced turmeric (4 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.20). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

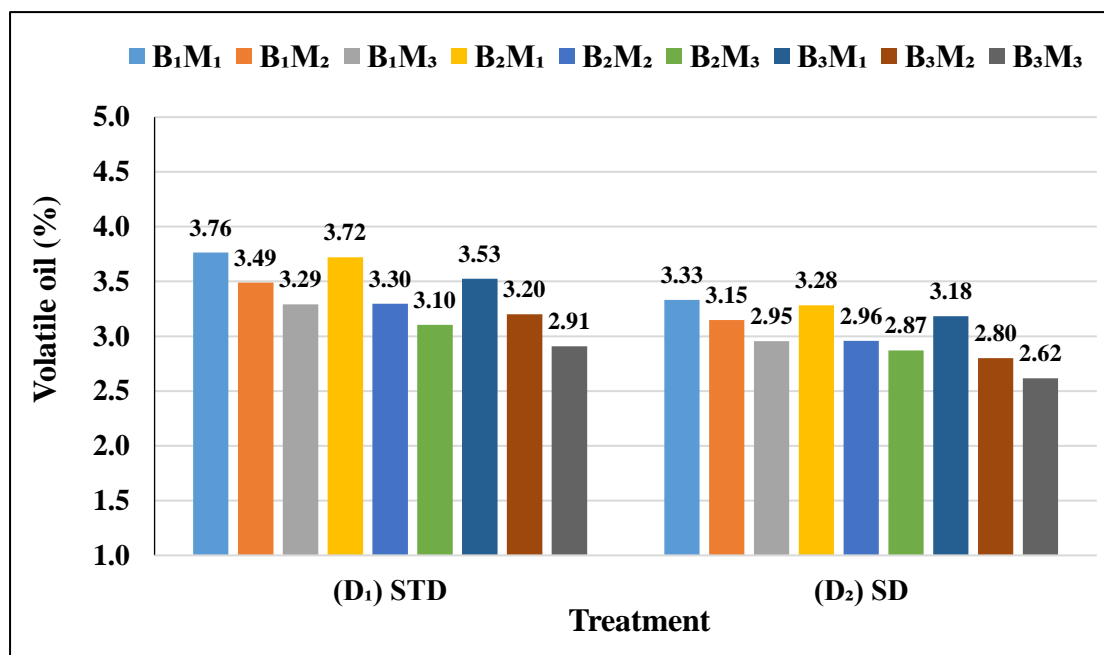


Fig. 4.85 Effect of different treatments on volatile oil of 4 mm turmeric slices

5) Effect of drying methods and sliced thickness (5 mm) on volatile oil

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.86) that volatile oil increased with solar tunnel drying methods. The highest volatile oil of 3.84% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest volatile oil of 2.70% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.20) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the volatile oil of sliced turmeric. The volatile oil content of solar tunnel drying D₁ (3.47%) was significantly higher than that of sun drying method D₂ (3.13%).

6) Effect of blanching temperature and slice thickness (5 mm) on volatile oil

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that volatile oil of sliced turmeric increased with decrease in blanching temperature. The highest volatile oil of 3.84% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest volatile oil of 2.70% was

obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.20) also revealed that the effect of blanching temperature (B) was found significant. The volatile oil content of B₁ (3.42%) was significantly higher than that of B₂ (3.31%) and B₃ (3.17%).

7) Effect of blanching time and slice thickness (5 mm) on volatile oil

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that volatile oil decreased with increase in blanching time. The highest volatile oil of 3.84% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest volatile oil of 2.70% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The highest yield of essential oil was obtained from unsliced samples dried in tunnel with boiling time of 15 and 30 minutes. The next higher values of 15 minutes of sliced samples dried in the tunnel. Thus, combinations of shorter boiling time of unsliced rhizome and tunnel drying resulted in higher essential oil, whereas longer boiling times combined with sun drying of sliced rhizome led to more loss of essential oil content (Hirko *et al.*, 2020).

The analysed data (Table 4.20) also revealed that the significant effect of blanching time (M). The volatile oil content of M₁ (3.54%) was significantly higher than that of M₂ (3.31%) and M₃ (3.05%).

8) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on volatile oil

The graphical presentation of the combined effect is shown in Fig. 4.86. The individual effect of D, B and M was found significant on the volatile oil of sliced turmeric (5 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.20). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

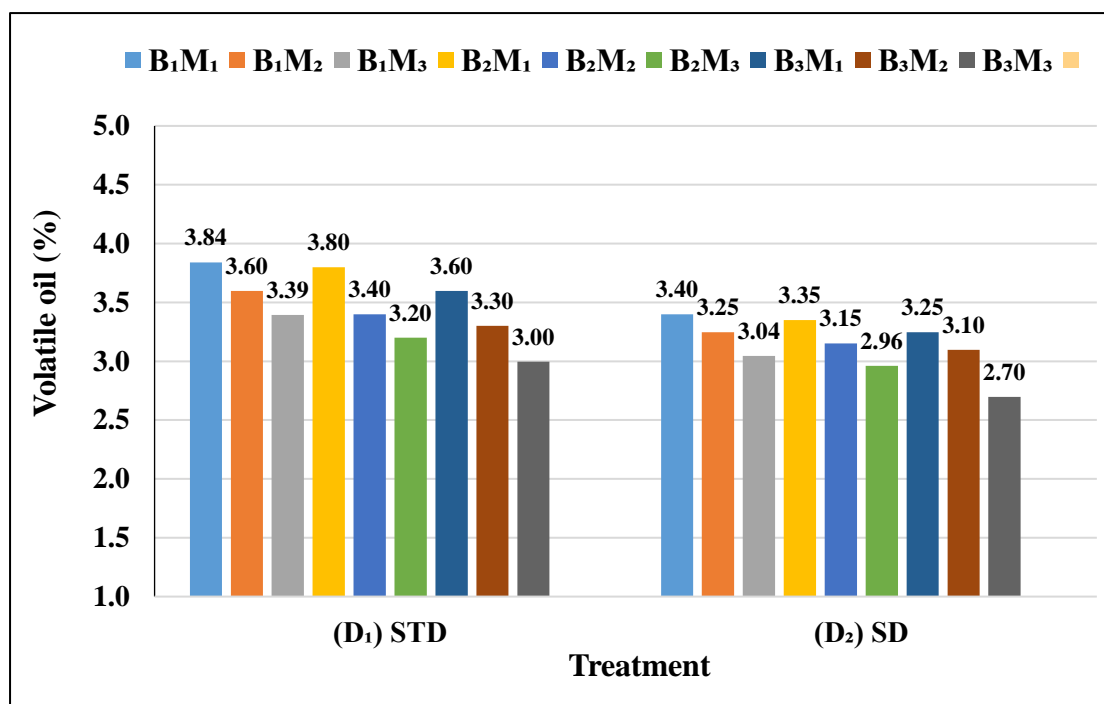


Fig. 4.86 Effect of different treatments on volatile oil of 5 mm turmeric slices

9) Effect of drying methods and whole turmeric on volatile oil

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.87) that volatile oil increased with solar tunnel drying methods. The highest volatile oil of 4.00% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest volatile oil of 3.04% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.20) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the volatile oil of whole turmeric. The volatile oil content of solar tunnel drying D₁ (3.67%) was significantly higher than that of sun drying method D₂ (3.26%).

10) Effect of blanching temperature and whole turmeric on volatile oil

The blanching of whole turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that volatile oil of whole turmeric decreased with increase in blanching temperature. The highest volatile oil of 4.00% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest volatile oil of 3.04% was

obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.20) also revealed that the effect of blanching temperature (B) was found significant. The volatile oil content of B₁ (3.50%) was significantly higher than that of B₂ (3.49%) and B₃ (3.41%).

11) Effect of blanching time and whole turmeric on volatile oil

The blanching of whole turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that volatile oil decreased with increase in blanching time. The highest volatile oil of 4.00% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest volatile oil of 3.04% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

Pruthi *et al.* (1993), Jose *et al.* (2005) reported traditional drying method could result in the loss of volatile oil of up to 25% by evaporation, and in the destruction of some of the light-sensitive oil constituents.

The analysed data (Table 4.20) also revealed that the significant effect of blanching time (M). The volatile oil content of M₁ (3.70%) was significantly higher than that of M₂ (3.47%) and M₃ (3.22%).

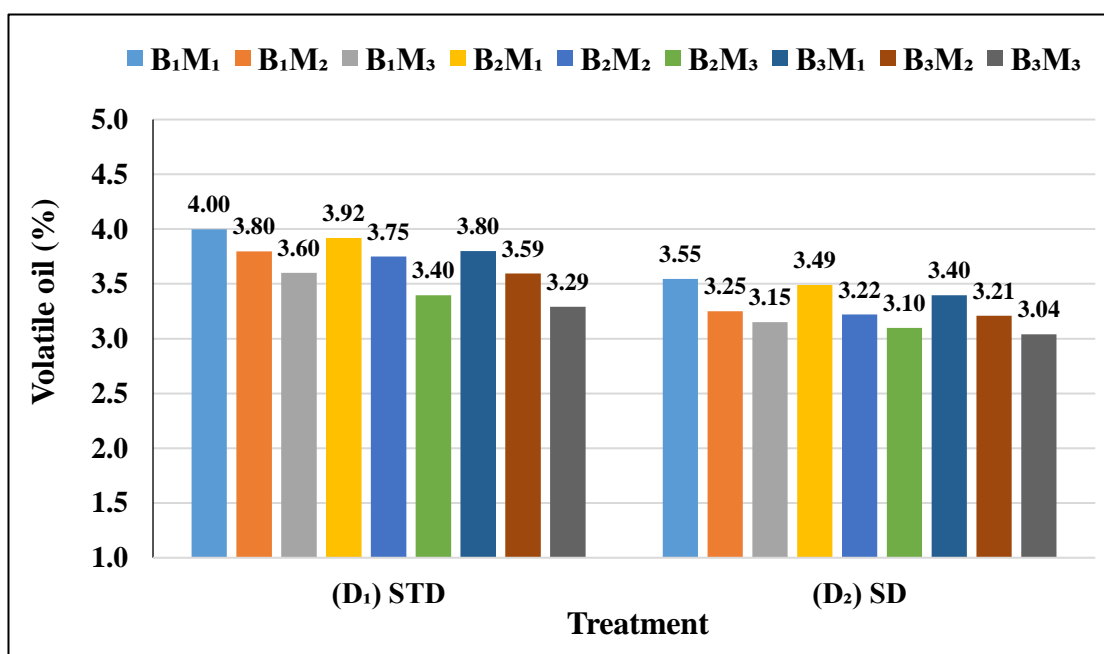


Fig. 4.87 Effect of different treatments on volatile oil of whole turmeric

12) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on volatile oil

The graphical presentation of the combined effect is shown in Fig. 4.87. The individual effect of D, B and M was found significant on the volatile oil of whole turmeric. However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.20). It may be the inherent nature of the factors. When interactions are non-significant, it means that levels of one factor are consistent over various levels of another factor.

4.8.1.8 Total phenol content

4.8.1.8.1 Effect of pre-treatments and drying methods on total phenol content

The total phenol content of sliced and whole turmeric influenced by blanching temperature, time and drying methods. The value of total phenol at different drying methods (i.e., solar tunnel drying and sun drying), blanching temperature (70°C, 80°C and 90°C), and blanching time (15 min, 30 min and 45 min) are presented in Table 4.21. The mean values of total phenol are presented in APPENDIX-H1 and APPENDIX-H2, respectively. Effects of these process variables on total phenol of turmeric are discussed hereunder.

Table 4.21 Effect of blanching temperatures and times on total phenol content of dried turmeric by different methods

| Sr. No. | Treatments | 4 mm | | 5 mm | | whole | |
|---------|-------------------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|----------------------|
| | | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD |
| 1 | B ₁ M ₁ | 2.97 | 2.89 | 2.88 | 2.80 | 2.77 | 2.44 |
| 2 | B ₁ M ₂ | 2.89 | 2.66 | 2.80 | 2.58 | 2.61 | 2.32 |
| 3 | B ₁ M ₃ | 2.77 | 2.46 | 2.69 | 2.38 | 2.36 | 2.08 |
| 4 | B ₂ M ₁ | 2.95 | 2.83 | 2.86 | 2.75 | 2.66 | 2.34 |
| 5 | B ₂ M ₂ | 2.85 | 2.56 | 2.76 | 2.48 | 2.59 | 2.28 |
| 6 | B ₂ M ₃ | 2.41 | 2.12 | 2.34 | 2.06 | 2.29 | 2.02 |
| 7 | B ₃ M ₁ | 2.91 | 2.73 | 2.82 | 2.65 | 2.63 | 2.32 |
| 8 | B ₃ M ₂ | 2.82 | 2.53 | 2.73 | 2.45 | 2.48 | 2.18 |
| 9 | B ₃ M ₃ | 2.21 | 1.94 | 2.14 | 1.89 | 2.04 | 1.80 |

Table 4.22 Effect of drying method, blanching temperatures and time on total phenol of sliced and whole dried turmeric rhizomes

| Total Phenol | | | |
|----------------------------------|------------|------------|--------------|
| Treatment | 4mm | 5mm | whole |
| Drying methods (D) | | | |
| D₁ (STD) | 2.75 | 2.67 | 2.49 |
| D₂ (SD) | 2.52 | 2.45 | 2.20 |
| S.Em.± | 0.02 | 0.02 | 0.03 |
| C.D. at 5 % | 0.07 | 0.06 | 0.08 |
| Blanching temperature (B) | | | |
| B₁ (70°C) | 2.77 | 2.69 | 2.43 |
| B₂ (80°C) | 2.62 | 2.54 | 2.36 |
| B₃ (90°C) | 2.52 | 2.45 | 2.24 |
| S.Em.± | 0.02 | 0.03 | 0.03 |
| C.D. at 5 % | 0.08 | 0.08 | 0.10 |
| Blanching time (M) | | | |
| M₁ (15 min.) | 2.88 | 2.79 | 2.53 |
| M₂ (30 min.) | 2.72 | 2.64 | 2.41 |
| M₃ (45 min.) | 2.32 | 2.25 | 2.10 |
| S.Em.± | 0.02 | 0.03 | 0.03 |
| C.D. at 5 % | 0.08 | 0.08 | 0.10 |
| C.V. % | 3.57 | 3.65 | 5.16 |
| D X B | | | |
| S.Em.± | 0.03 | 0.04 | 0.05 |
| C.D. at 5 % | NS | NS | NS |
| D X M | | | |
| S.Em.± | 0.03 | 0.04 | 0.05 |
| C.D. at 5 % | NS | NS | NS |
| B X M | | | |
| S.Em.± | 0.05 | 0.05 | 0.06 |
| C.D. at 5 % | 0.14 | 0.11 | 0.09 |
| D X B X M | | | |
| S.Em.± | 0.07 | 0.06 | 0.09 |
| C.D. at 5 % | NS | NS | NS |

1) Effect of drying methods and sliced thickness (4 mm) on total phenol

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.88) that total phenol increased with solar tunnel

drying methods. The highest total phenol of 2.97% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total phenol of 1.94% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.22) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the total phenol of sliced turmeric. The total phenol content of solar tunnel drying D₁ (2.75%) was significantly higher than that of sun drying method D₂ (2.52%).

2) Effect of blanching temperature and sliced thickness (4 mm) on total phenol

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that total phenol of sliced turmeric decreased with increase in blanching temperature. The highest total phenol of 2.97% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total phenol of 1.94% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.22) also revealed that the effect of blanching temperature (B) was found significant. The total phenol content of B₁ (2.77%) was significantly higher than that of B₂ (2.62%) and B₃ (2.52%).

3) Effect of blanching time and slice thickness (4 mm) on total phenol

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total phenol decreased with increase in blanching time. The highest total phenol of 2.97% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total phenol of 1.94% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The higher blanching temperature and time applied, the greater losses occur in the total phenolic and flavonoid amount and in the antioxidant capacity of vegetables (Goncalves *et al.*, 2009; Jaiswal *et al.*, 2012; Volden *et al.*, 2009). However, an increase in the total phenolic amount at longer processing time has also been reported (Jaiswal

et al., 2012). Furthermore, an increase in the total phenolic content and antioxidant capacity of some vegetables after blanching has also been observed (Managa *et al.*, 2019).

The analysed data (Table 4.22) also revealed that the significant effect of blanching time (M). The total phenol content of M₁ (2.88%) was significantly higher than that of M₂ (2.72%) and M₃ (2.32%).

4) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total phenol

The graphical presentation of the combined effect is shown in Fig. 4.88. The individual effect of D, B and M was found significant on the total phenol of sliced turmeric (4 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.22). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

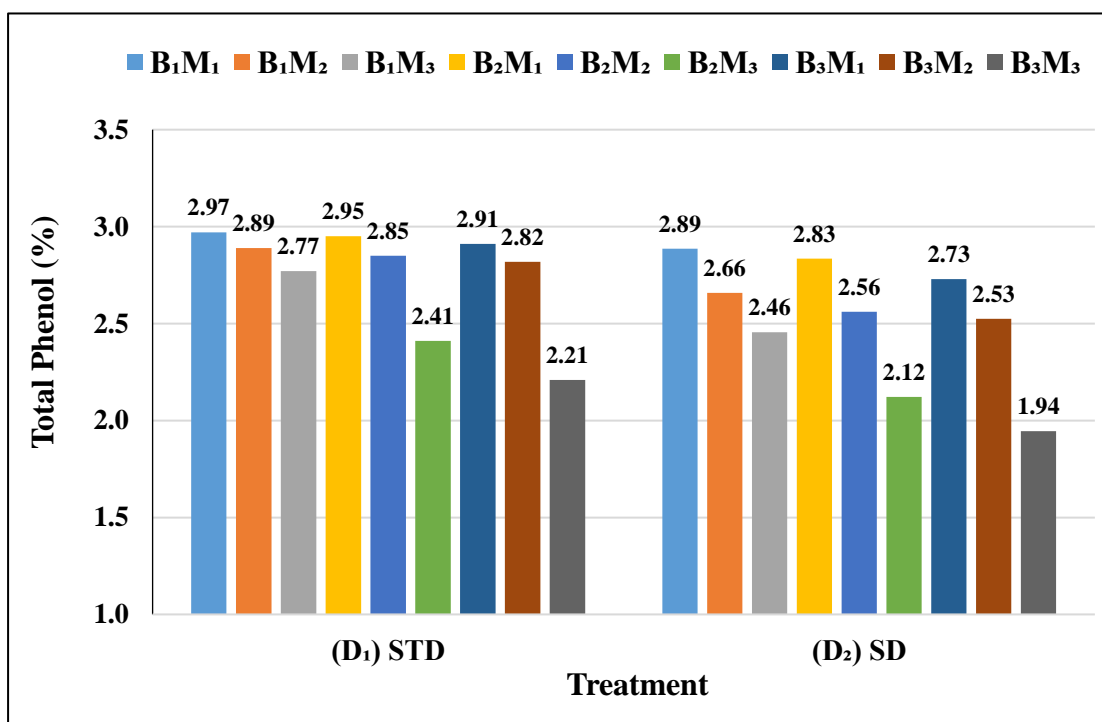


Fig. 4.88 Effect of different treatments on total phenol content of 4 mm turmeric slices

5) Effect of drying methods and sliced thickness (5 mm) on total phenol

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.89) that total phenol increased with solar tunnel drying methods. The highest total phenol of 2.97% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total phenol of 1.94% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.22) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the total phenol of sliced turmeric. The total phenol content of solar tunnel drying D₁ (2.67%) was significantly higher than that of sun drying method D₂ (2.45%).

6) Effect of blanching temperature and slice thickness (5 mm) on total phenol

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that total phenol of sliced turmeric increased with decrease in blanching temperature. The highest total phenol of 2.97% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total phenol of 1.94% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.22) also revealed that the effect of blanching temperature (B) was found significant. The total phenol content of B₁ (2.69%) was significantly higher than that of B₂ (2.54%) and B₃ (2.45%).

7) Effect of blanching time and slice thickness (5 mm) on total phenol

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total phenol decreased with increase in blanching time. The highest total phenol of 2.97% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total phenol of 1.94% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.22) also revealed that the significant effect of blanching time (M). The total phenol content of M₁ (2.79%) was significantly higher than that of M₂ (2.64%) and M₃ (2.25%).

Capecka *et al.*, (2005) explained that the drying process may result in high or low levels of TPC depending on type of phenolic compounds present in the plant material and their location in the cell. Multari *et al.*, (2018) suggested that higher temperature can improve the solubility of phenolic compounds leading to the breakdown of cellular structure. Longer drying time and higher temperature cause degradation of the polyphenol compounds.

8) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total phenol

The graphical presentation of the combined effect is shown in Fig. 4.89. The individual effect of D, B and M was found significant on the total phenol of sliced turmeric (5 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.22). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

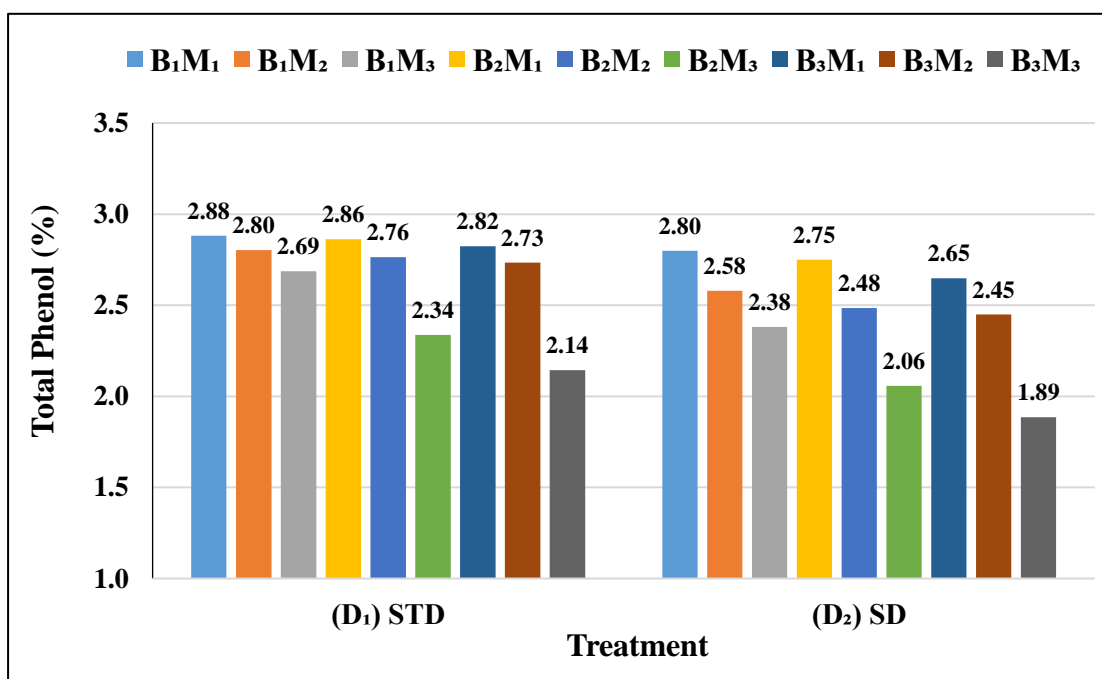


Fig. 4.89 Effect of different treatments on total phenol content of 5 mm turmeric slices

9) Effect of drying methods and whole turmeric on total phenol

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.90) that total phenol increased with solar tunnel drying methods. The highest total phenol of 2.77% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total phenol of 1.80% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.22) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the total phenol of whole turmeric. The total phenol content of solar tunnel drying D₁ (2.49%) was significantly higher than that of sun drying method D₂ (2.20%).

10) Effect of blanching temperature and whole turmeric on total phenol

The blanching of turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that total phenol of turmeric decreased with increase in blanching temperature. The highest total phenol of 2.77% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total phenol of 1.80% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.22) also revealed that the effect of blanching temperature (B) was found significant. The total phenol content of B₁ (2.43%) was significantly higher than that of B₂ (2.36%) and B₃ (2.24%).

11) Effect of blanching time and whole turmeric on total phenol

The blanching of whole turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that total phenol decreased with increase in blanching time. The highest total phenol of 2.77% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest total phenol of 1.80% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The higher blanching temperature and time applied, the greater losses occur in the total phenolic and flavonoid amount and in the antioxidant capacity of vegetables (Goncalves *et al.*, 2009; Jaiswal *et al.*, 2012; Volden *et al.*, 2009). The analysed data

(Table 4.22) also revealed that the significant effect of blanching time (M). The total phenol content of M₁ (2.53%) was significantly higher than that of M₂ (2.41%) and M₃ (2.10%).

12) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on total phenol

The graphical presentation of the combined effect is shown in Fig. 4.90. The individual effect of D, B and M was found significant on the total phenol of whole turmeric. However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.22). It may be the inherent nature of the factors. When interactions are non-significant, it means that levels of one factor are consistent over various levels of another factor.

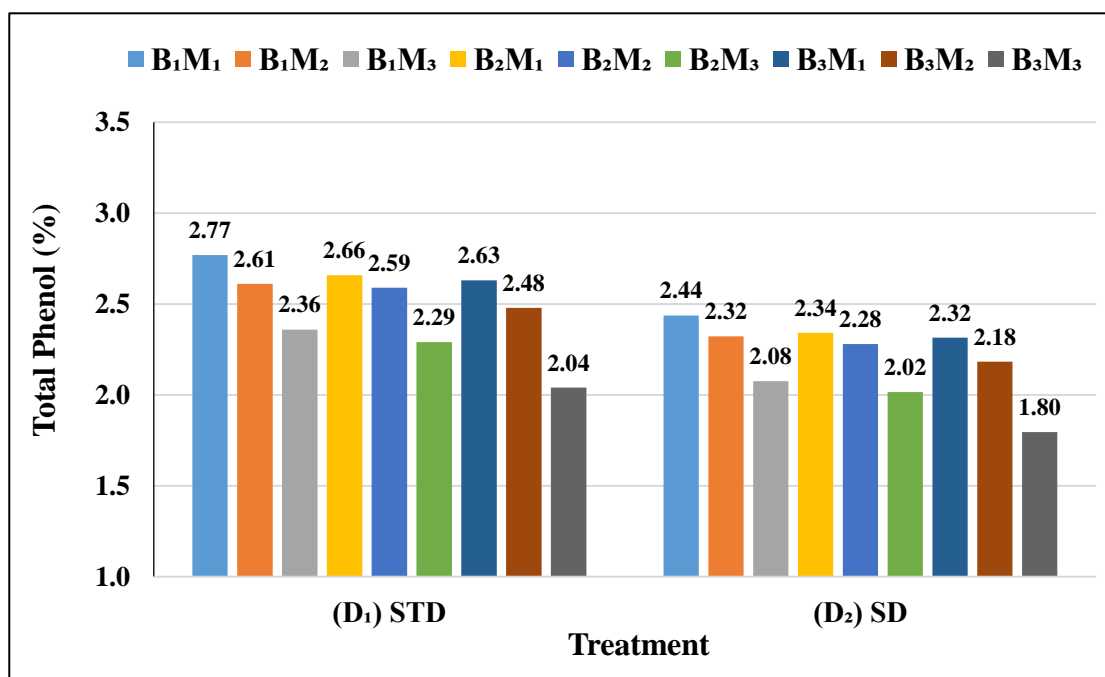


Fig. 4.90 Effect of different treatments on total phenol content of whole turmeric

4.8.1.9 Antioxidant activity

4.8.1.9.1 Effect of pretreatments and drying methods on antioxidant activity

The antioxidant activity of sliced and whole turmeric influenced by blanching temperature, time and drying methods. The value of antioxidant activity at different drying methods (i.e., solar tunnel drying and sun drying), blanching temperature (70°C, 80°C and 90°C), and blanching time (15 min, 30 min and 45 min) are presented in Table

4.23. The mean values of antioxidant activity are presented in APPENDIX-H1 and APPENDIX-H2, respectively. Effects of these process variables on antioxidant activity of turmeric are discussed hereunder.

1) Effect of drying methods and sliced thickness (4 mm) on antioxidant activity

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.91) that antioxidant activity increased with solar tunnel drying methods. The highest antioxidant activity of 44.86% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest antioxidant activity of 30.06% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.24) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the antioxidant activity of sliced turmeric. The antioxidant activity content of solar tunnel drying D₁ (40.86%) was significantly higher than that of sun drying method D₂ (37.18%).

Table 4.23 Effect of different blanching temperatures and times on antioxidant activity of dried turmeric by different methods

| Sr. No. | Treatments | 4 mm | | 5 mm | | whole | |
|---------|-------------------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|----------------------|
| | | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD | (D ₁) STD | (D ₂) SD |
| 1 | B ₁ M ₁ | 44.86 | 42.59 | 46.25 | 43.91 | 42.09 | 39.96 |
| 2 | B ₁ M ₂ | 41.93 | 39.45 | 43.23 | 40.67 | 39.34 | 37.01 |
| 3 | B ₁ M ₃ | 38.97 | 34.72 | 40.18 | 35.79 | 36.56 | 32.57 |
| 4 | B ₂ M ₁ | 44.05 | 41.09 | 45.41 | 42.36 | 41.32 | 38.55 |
| 5 | B ₂ M ₂ | 41.50 | 38.29 | 42.78 | 39.47 | 38.93 | 35.92 |
| 6 | B ₂ M ₃ | 36.88 | 32.10 | 38.02 | 33.09 | 34.60 | 30.11 |
| 7 | B ₃ M ₁ | 43.70 | 39.97 | 45.05 | 41.21 | 41.00 | 37.50 |
| 8 | B ₃ M ₂ | 40.34 | 36.38 | 41.59 | 37.50 | 37.85 | 34.13 |
| 9 | B ₃ M ₃ | 33.85 | 30.06 | 34.90 | 30.99 | 31.76 | 28.20 |

Table 4.24 Effect of drying method, blanching temperatures and time on antioxidant activity of sliced and whole dried turmeric rhizomes

| Antioxidant Activity | | | |
|----------------------------------|------------|------------|--------------|
| Treatment | 4mm | 5mm | whole |
| Drying methods (D) | | | |
| D₁ (STD) | 40.68 | 41.93 | 38.16 |
| D₂ (SD) | 37.18 | 38.33 | 34.88 |
| S.Em.± | 0.29 | 0.34 | 0.49 |
| C.D. at 5 % | 0.87 | 1.00 | 1.47 |
| Blanching temperature (B) | | | |
| B₁ (70°C) | 40.42 | 41.67 | 37.92 |
| B₂ (80°C) | 38.98 | 40.19 | 36.57 |
| B₃ (90°C) | 37.38 | 38.54 | 35.07 |
| S.Em.± | 0.36 | 0.41 | 0.61 |
| C.D. at 5 % | 1.06 | 1.23 | 1.80 |
| Blanching time (M) | | | |
| M₁ (15 min.) | 42.71 | 44.03 | 40.07 |
| M₂ (30 min.) | 39.65 | 40.87 | 37.19 |
| M₃ (45 min.) | 34.43 | 35.49 | 32.30 |
| S.Em.± | 0.36 | 0.41 | 0.61 |
| C.D. at 5 % | 1.06 | 1.23 | 1.80 |
| C.V. % | 3.19 | 3.56 | 5.74 |
| D X B | | | |
| S.Em.± | 0.51 | 0.58 | 0.86 |
| C.D. at 5 % | NS | NS | NS |
| D X M | | | |
| S.Em.± | 0.51 | 0.58 | 0.86 |
| C.D. at 5 % | NS | NS | NS |
| B X M | | | |
| S.Em.± | 0.62 | 0.72 | 1.05 |
| C.D. at 5 % | 2.45 | 2.78 | 3.05 |
| D X B X M | | | |
| S.Em.± | 0.88 | 1.01 | 1.48 |
| C.D. at 5 % | NS | NS | NS |

2) Effect of blanching temperature and sliced thickness (4 mm) on antioxidant activity

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that antioxidant activity of sliced turmeric decreased with increase in blanching temperature. The highest antioxidant activity of 44.86% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest antioxidant activity of 30.06% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.24) also revealed that the effect of blanching temperature (B) was found significant. The antioxidant activity of B₁ (40.42%) was significantly higher than that of B₂ (38.98%) and B₃ (37.38%).

3) Effect of blanching time and slice thickness (4 mm) on antioxidant activity

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that antioxidant activity decreased with increase in blanching time. The highest antioxidant activity of 44.86% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest antioxidant activity of 30.06% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The higher blanching temperature and time applied, the greater losses occur in the total phenolic and flavonoid amount and in the antioxidant capacity of vegetables (Goncalves *et al.*, 2009; Jaiswal *et al.*, 2012; Volden *et al.*, 2009). However, an increase in the total phenolic amount at longer processing time has also been reported (Jaiswal *et al.*, 2012). Furthermore, an increase in the antioxidant capacity of some vegetables after blanching has also been observed (Managa *et al.*, 2019).

The analysed data (Table 4.24) also revealed that the significant effect of blanching time (M). The antioxidant activity of M₁ (42.71%) was significantly higher than that of M₂ (39.65%) and M₃ (34.43%).

4) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on antioxidant activity

The graphical presentation of the combined effect is shown in Fig. 4.91. The individual effect of D, B and M was found significant on the antioxidant activity of sliced turmeric (4 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.24). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

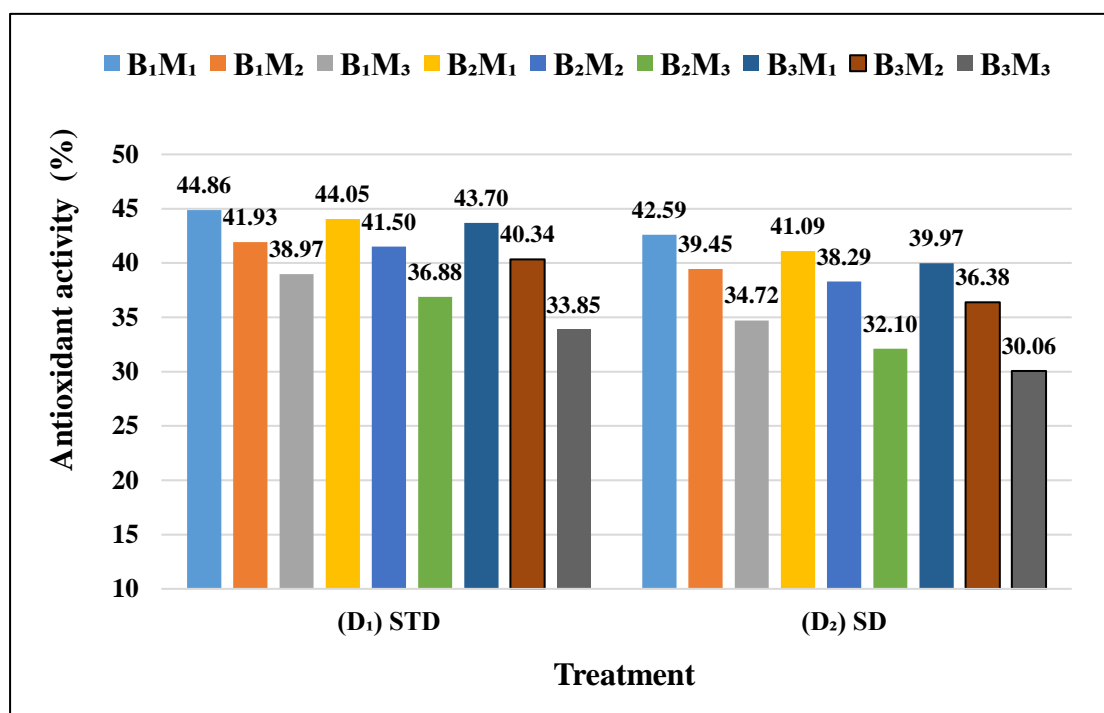


Fig. 4.91 Effect of different treatments on antioxidant activity of 4 mm turmeric slices

5) Effect of drying methods and sliced thickness (5 mm) on antioxidant activity

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.92) that antioxidant activity increased with solar tunnel drying methods. The highest antioxidant activity of 46.25% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest antioxidant activity of 30.99% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.24) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the antioxidant activity of sliced turmeric. The antioxidant activity of solar tunnel drying D₁ (41.93%) was significantly higher than that of sun drying method D₂ (38.33%).

6) Effect of blanching temperature and slice thickness (5 mm) on antioxidant activity

The blanching of sliced turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that antioxidant activity of sliced turmeric decreased with increase in blanching temperature. The highest antioxidant activity of 46.25% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest antioxidant activity of 30.99% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.24) also revealed that the effect of blanching temperature (B) was found significant. The antioxidant activity of B₁ (41.67%) was significantly higher than that of B₂ (40.19%) and B₃ (38.54%).

7) Effect of blanching time and slice thickness (5 mm) on antioxidant activity

The blanching of sliced turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that antioxidant activity decreased with increase in blanching time. The highest antioxidant activity of 46.25% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest antioxidant activity of 30.99% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The yields of antioxidant activity between the 15 minute (92.77%) and the 30 minute (90.34%) blanched treated samples reported (Green et al., 2014). The antioxidant activity of lower time period blanched turmeric was more as compared to longer period of blanched turmeric.

The analysed data (Table 4.24) also revealed that the significant effect of blanching time (M). The antioxidant activity of M₁ (44.03%) was significantly higher than that of M₂ (40.87%) and M₃ (35.49%).

8) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on antioxidant activity

The graphical presentation of the combined effect is shown in Fig. 4.92. The individual effect of D, B and M was found significant on the antioxidant activity of sliced turmeric (5 mm). However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.24). It may be the inherent nature of the factors. When interaction is non-significant, it means that levels of one factor are consistent over various levels of another factor.

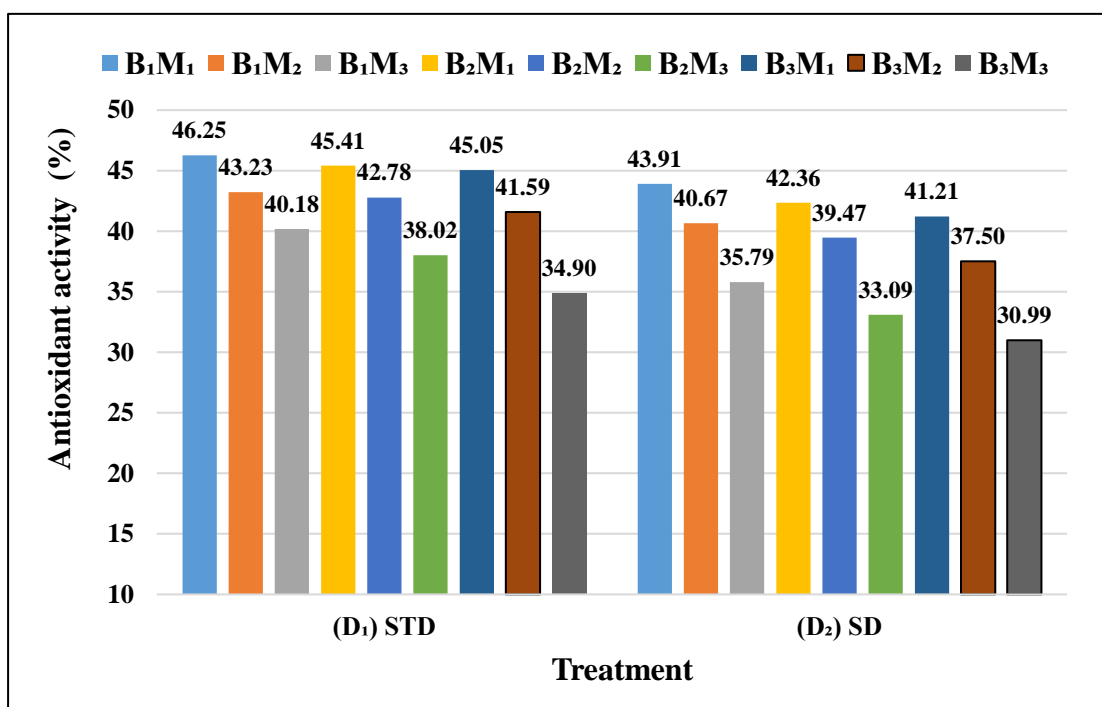


Fig. 4.92 Effect of different treatments on antioxidant activity of 5 mm turmeric slices

9) Effect of drying methods and whole turmeric on antioxidant activity

The drying methods were kept at two levels i.e., solar tunnel drying and sun drying. It can be clearly seen (Fig. 4.93) that antioxidant activity increased with solar tunnel drying methods. The highest antioxidant activity of 42.09% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest antioxidant activity of 28.20% was obtained in treatment B₃M₃D₂.

The analysed data (Table 4.24) revealed that the effect of drying methods (D) was found significantly indicated that the solar tunnel drying increased the antioxidant

activity of whole turmeric. The antioxidant activity of solar tunnel drying D₁ (38.16%) was significantly higher than that of sun drying method D₂ (34.88%).

10) Effect of blanching temperature and whole turmeric on antioxidant activity

The blanching of whole turmeric for difference blanching temperature was carried out at three levels i.e., 70°C, 80°C and 90°C. It was observed that antioxidant activity of whole turmeric decreased with increase in blanching temperature. The highest antioxidant activity of 42.09% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest antioxidant activity of 28.20% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried).

The analysed data (Table 4.24) also revealed that the effect of blanching temperature (B) was found significant. The antioxidant activity of B₁ (37.92%) was significantly higher than that of B₂ (36.57%) and B₃ (35.07%).

11) Effect of blanching time and whole turmeric on antioxidant activity

The blanching of whole turmeric for difference blanching time was carried out at three levels i.e., 15 min, 30 min and 45 min. It was observed from the figure that antioxidant activity decreased with increase in blanching. The highest antioxidant activity of 42.09% was obtained in treatment B₁M₁D₁ (blanching temperature 70°C + blanching time 15 min + solar tunnel dried) and lowest antioxidant activity of 28.20% was obtained in treatment B₃M₃D₂ (blanching temperature 90°C + blanching time 45 min + sun dried). The analysed data (Table 4.24) also revealed that the significant effect of blanching time (M). The antioxidant activity of M₁ (40.07%) was significantly higher than that of M₂ (37.19%) and M₃ (32.30%).

The higher blanching temperature and time applied, the greater losses occur in the total phenolic and flavonoid amount and in the antioxidant capacity of vegetables (Goncalves *et al.*, 2009; Jaiswal *et al.*, 2012; Volden *et al.*, 2009). However, an increase in the total phenolic amount at longer processing time has also been reported (Jaiswal *et al.*, 2012). Furthermore, an increase in the antioxidant capacity of some vegetables after blanching has also been observed (Managa *et al.*, 2019).

12) Combined effect of drying method (D), blanching temperature (B) and blanching time (M) on antioxidant activity

The graphical presentation of the combined effect is shown in Fig. 4.93. The individual effect of D, B and M was found significant on the antioxidant activity of whole turmeric. However, the interaction between DxB, DxM and DxBxM was non-significant except BxM (Table 4.24). It may be the inherent nature of the factors. When interactions are non-significant, it means that levels of one factor are consistent over various levels of another factor.

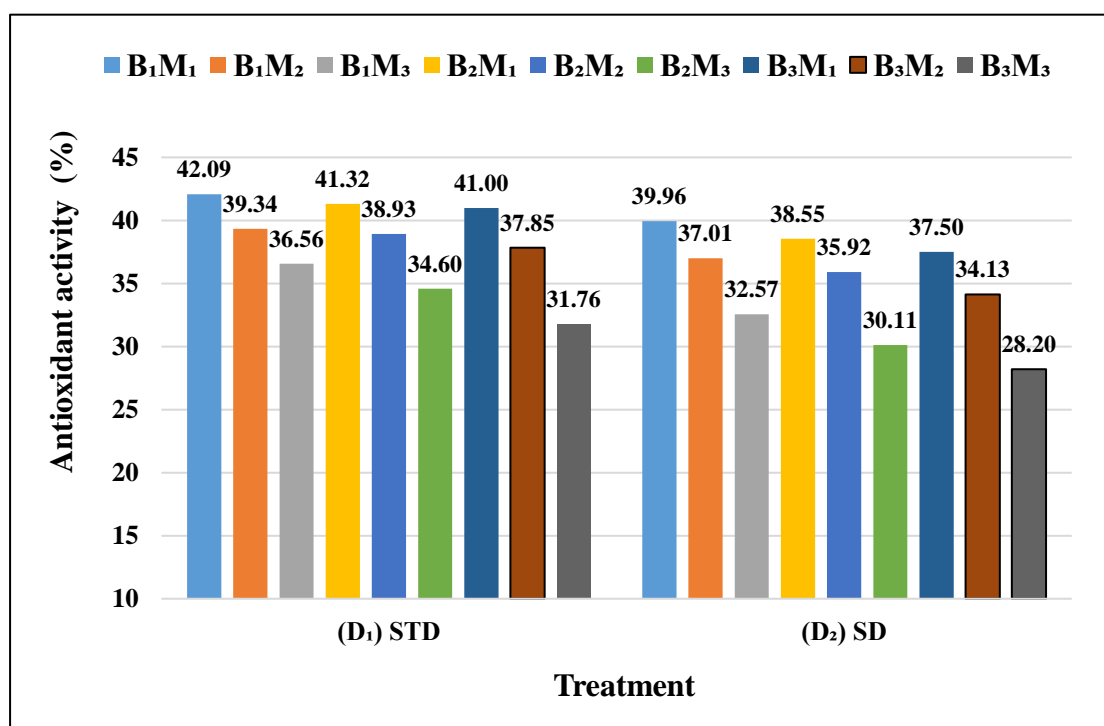


Fig. 4.93 Effect of different treatments on antioxidant activity of whole turmeric

4.8.2 Combined method studied for preparation of turmeric powder through solar tunnel drying

The details of the different steps followed in the drying of blanched whole turmeric are elaborated as under in the process flow chart (Fig. 4.166). From the present investigation, on the basis of biochemical parameters it is concluded that the best quality turmeric powder is prepared by solar tunnel dried whole turmeric rhizomes blanched at 70°C for 15 min.

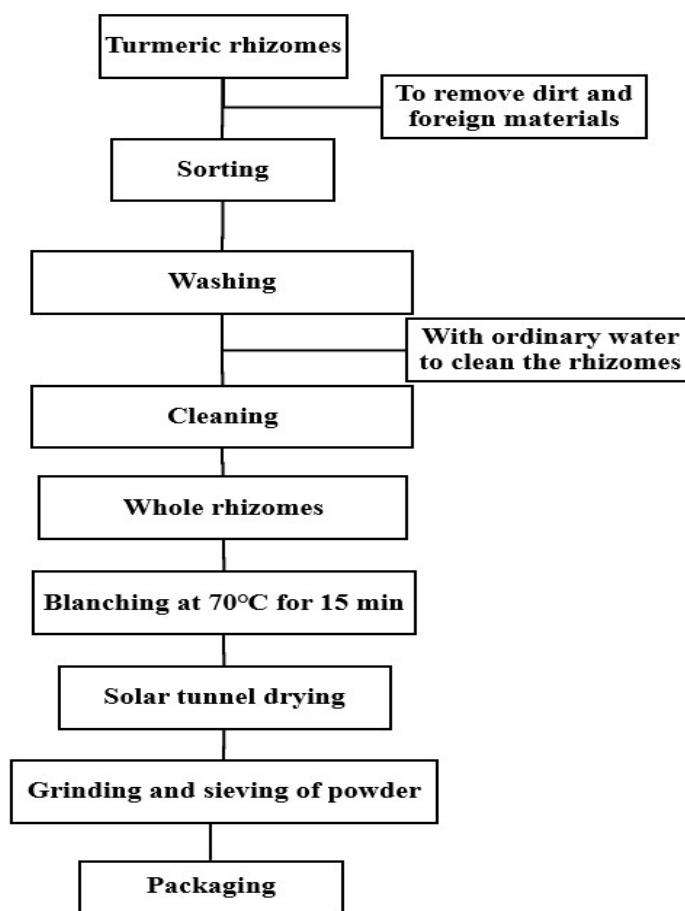


Fig. 4.94 Process flow chart for drying of turmeric

4.9 Economic Feasibility of Solar Tunnel Dryer

- The different components of solar tunnel dryer, viz., **RCC Foundation, complete STD structure, viz.,** drying trays (64 nos.) along with tray stands (4 nos.), 20 μ UV resistance polyethylene cover and air ventilating devices, electric and analytical instruments and solar air collectors, etc., as well as details of materials and accessories used for each component with their fabrication charges are reported in Table 4.25.
- The total cost of the solar tunnel dryer along with their fabrication charges is Rs. 284000/- as well as cost of solar tunnel dryer including additional heating device (3 flat plate solar collectors) is Rs. 360200

Table 4.25 Details of Fabrication Cost of Solar Tunnel Dryer

| Sr. No. | Details of Item | Specification | Rate | Total Cost |
|------------------------------|---|--------------------------------|------------------|--------------|
| STD RCC Foundation | | | | |
| 1 | STD construction Sand, cement, stone, MS angle, MS rods, etc. required for 10.80 m x 5.80m x 0.30 m with construction and all the charges. | 10.80 m x 5.80m x 0.30 m | --- | 561000 |
| | Red oxide | 4 lit | 172 per lit | 688 |
| | Thermocol sheet | 64 sq.m. | 750 per sq.m | 4800 |
| | Paint brush | 4 no. | 108 per brush | 432 |
| | Black paint (Apco Asian) | 16 lit | 240 per lit | 3840 |
| | Square pipe (50 mm x 50 mm x 2 mm) | 20 kg | 73 / kg | 1460 |
| | Accessories, viz., Nut Bolt, MS strips, rivets, welding rods, m-seal, emery papers, etc. and fitting charges. | -- | -- | 4200 |
| Total Foundation Cost | | | | 67420 |
| STD STRUCTURE | | | | |
| 2 | GI Sheet (58 cm x 65 cm x30 cm) | 20 kg | 68 | 1360 |

| | | | | |
|--|--|------------|---------------|---------------|
| 3 | Square pipe (50 mm x 50 mm x 2 mm) | 30 kg | 71 per kg | 2130 |
| | Square pipe (40 mm x 40 mm x 1.2 mm) | 227 kg | | 16117 |
| | Square pipe (25 mm x 25 mm x 1.2 mm) | 182 kg | | 12922 |
| | Square pipe (35 mm x 35 mm x 2 mm) | 450 kg | | 31950 |
| | Fabrication charges, Bending, riveting, fixing, welding, painting and other charges | -- | -- | 12000 |
| 4 | UV resistance 200 μ Polyethylene Plastic and fitting charges | 9 m x 25 m | 1 roll | 11710 |
| 5 | SS Tray (700 mm x 700 mm x 50 mm) <ul style="list-style-type: none"> • Wire mesh (SS 304) - 10 to 11 perforations per inch. • Wire mesh holding frame and side support made from SS 202 strips. • Fabrication charges | 64 | 1400 per tray | 89600 |
| Total Cost of STD Structure | | | | 181149 |
| Air Ventilating Devices | | | | |
| 6 | Turbo ventilators (2 nos) and fitting accessories, Round bar, nut bolt, couple bushing, strip, bushing hole, angle strip, airtight ribbon and fitting charges | --- | ----- | 7755 |
| 7 | Exhaust fans (2 nos.) and accessories fitting charges | --- | ----- | 6285 |
| Total Cost of Ventilating Devices | | | | 14040 |
| Electric and analytical instruments | | | | |
| 8 | STD Electric Fittings, PVC syntax box, modular box, modular switch (15 A), modular socket (15 A), extension board, cables, etc. and fitting charges | ---- | --- | 2212 |
| 9 | K - Temp Sensor with 6 m length grade sensor cable, fiber glass graded, connector, core wires and fitting charges. | ---- | --- | 4439 |

| | | | | |
|--|---|-------------------|----|---------------|
| 10 | Temperature controller and accessories, MCB, Al sheet strip, Temp Sensor and fitting charges. | -- | -- | 14000 |
| Total cost of Solar Tunnel Dryer (excluding solar collectors) | | | | 284000 |
| External Heating System | | | | |
| 11 | Solar air collector with fitting charges | 8 ' x 4 ' x 0.5 ' | | 76200 |
| Total cost of Solar Tunnel Dryer (including solar collectors) | | | | 360200 |

Table 4.26 Cost of Operation of Solar Assisted Dryer for Turmeric Rhizomes

| (A) Considerations | | | | |
|-------------------------------------|--------------------------------------|---|-------------------------|-------------------------------------|
| Sr. No. | Particular | Amount | Remarks | |
| 01 | Cost of machine | Rs. 284000 | Table 4.25 | |
| 02 | Capacity of machine | 500 kg / batch (i.e.,22 days for turmeric rhizomes) | -- | |
| 03 | Operator | labors ₹ Rs. 345.20/day of 8 hours | -- | |
| 04 | Electric Power consumption | ----- | 70.70/batch | |
| 05 | Depreciation | 10 % per annum | -- | |
| 06 | Interest | 10 % per annum | -- | |
| 07 | Housing | 1 % per annum | -- | |
| 08 | Life of machine | 20 years | -- | |
| 09 | Annual use (For multi crops) | 1050 / year | 150 days x 7 hour | |
| 10 | Repair and maintenance | 3 % per annum | -- | |
| (B) Head wise operating cost | | | | |
| Sr. No. | Particular & Formula | Calculation | Amount (Rs./day) | Amount {Rs./batch (22 days)} |
| 01 | Depreciation (D) = $\{[C-H]/[LXH]\}$ | $[284000-28400]/[20 \times 1050]$ | 12.15 | 267.30 |

| | | | | |
|---------------------------------|---|---|---------------|----------------|
| 02 | Interest (I) = $\{[C+S]/2\} \times \{i/H\}$ | $\{[284000-28400]/2\} \times \{10/[100 \times 1050]\}$ | 12.17 | 267.74 |
| 03 | Repair and maintenance charge | $[(284000-28400) \times 3]/[100 \times 20 \times 1050]$ | 0.36 | 7.92 |
| 04 | Housing charge | $[284000 \times 1]/[100 \times 1050]$ | 2.70 | 59.40 |
| 05 | Electric charges (Exhaust fan-0.557 HP, 1400 rpm) | 8500 watt per day | 5.05 | 111.10 |
| 06 | Labour wages | (345.20 + 345.20)/day for 2 days = 4 345.20/day for 10 days = 10 Total 14 labors ₹ 345.20 | 345.20 | 4832.8 |
| Total cost of drying Rs. | | | 377.63 | 5546.26 |

(C) Total cost of drying turmeric rhizomes

| Sr. No. | Particular | Amount (Rs.) |
|--|--|----------------|
| 01 | Total cost of solar tunnel drying fresh turmeric rhizomes (500 kg) | 5546.26 |
| 02 | Cost of solar tunnel drying per kg of fresh rhizomes (=5546.26/500) | 11.10 |
| 03 | Cost of solar tunnel drying per kg of dried turmeric rhizomes (=5546.26/112) | 49.52 |
| 04 | Cost of sun drying per kg of dried turmeric rhizomes (Table 4.27) | 53.35 |
| Elements of Agril. Engg. by Dr. J. Sahay 2006 | | |

Table 4.27 Comparison of cost for drying of turmeric rhizomes by traditional sun drying and solar tunnel dryer

| Sr. No. | Particulars | Drying Methods | |
|---------|--|------------------------------------|--------------------------------------|
| | | Solar Tunnel Dryer | Sun Drying |
| 01 | Initial Cost, Rs. | 284000 | -- |
| 02 | Capacity, kg | 500 (by 14 labor) | 500 (by 16 labor) |
| 03 | Labour, man-h | 128 | 352 |
| 04 | Power requirement, hp | 1.1 | -- |
| 05 | Drying time, days | 22 | 40 |
| 06 | Dried weight of turmeric rhizomes, kg | 112 | 103.52 |
| 07 | Dried weight of turmeric rhizomes kg/500 kg fresh turmeric rhizomes | 112 | 103.52 |
| 08 | Drying cost, Rs. / kg of turmeric rhizomes | 49.52 | 53.35 |
| 09 | Percent recovery of dried turmeric rhizomes % (in terms of kg/100 kg) | 22.40% (22.40 kg) | 20.70 % (20.70 kg) |
| 10 | Market value of dried turmeric powder per kg | Rs. 330 per kg | Rs. 270 per kg |
| 11 | Benefits in terms of Rupees /100 kg of dried turmeric rhizomes, Rs. | 561.00 (1.70kg x 330) | --- |
| 12 | Drying cost, Rs. / kg of dried turmeric after considering loss of turmeric rhizomes | 49.52 (Rs5546.26/112 kg) | 53.35 (Rs5523.2/103.52 kg) |

Extract of Cost-economic analysis

- There is no kind of loss of turmeric rhizomes has occurred during the drying of turmeric rhizomes using a solar tunnel dryer.
- Solar-dried turmeric powder costs Rs. 330 per kg. The solar dryer is better because it gives 1.7 kg more turmeric than the traditional sun drying method. When we use sun drying, we lose some turmeric because of the environment and handling losses during drying. Sun drying results in a loss of 1.7 kg per 100 kg of fresh turmeric during the drying process.
- The loss of 1.7 kg in sun-drying represents 8.20% of the final recovery, which is 20.70 kg in the sun-dried method.
- The recovery level of dried turmeric rhizomes was higher in the solar tunnel dryer (22.40 kg/q) as compared to the traditional sun drying method (20.70 kg/q) in terms of quantity 1.70 kg/q and in terms of Rs. 561.00 per 100 kg of turmeric rhizomes. In other words, farmers of the Saurashtra region will gain additional benefits of Rs. 2805 per batch of 500 kg of fresh turmeric rhizomes by adopting a solar tunnel dryer.
- So, producer of the Saurashtra region will benefit by using solar tunnel dryers in terms of minimizing post-harvest loss of turmeric rhizomes (8.2 %) as well as good returns of their final product (Rs. 561.00/q) as compared to the traditional sun drying method.

Carbon Credited in Solar Tunnel Drying:**▪ Turmeric :**

- Weight of fresh turmeric rhizomes : 500 kg
- Initial Moisture Content : 78.25 % (wb) (i.e., 360 % (db))
- Final Moisture Content : 8.90 % (wb) (i.e., 9.76 % (db))
- Weight of water : 388 kg
- Weight of dry matter : 112 kg
- Volume of water removed (Mw) : 434.91 kg
- Dry weight of turmeric : 112 kg

- Specific heat of turmeric : 3.90 kJ/kg⁰K
- Sensible heat of product : 11026 kJ
- Specific heat water : 4.186 kJ/kg⁰K
- Sensible heat of water : 45513.4 kJ
- Latent heat of water : 982899 kJ
- Total : 11026 + 45513 + 982899 = 1039439 kJ
- Total Energy Required in solar tunnel dryer: 288.733 kWh
- Emission of the carbon reduced by solar dryer: 259.86 Kg CO₂
- Thermal efficiency of Mechanical Dryer : 70 %
- Total Energy Required in Mechanical dryer: 412.47 kWh
- Emission of the carbon produced by mechanical dryer: 371.288 Kg CO₂

CHAPTER V

SUMMARY AND CONCLUSIONS

5.1 Summary

India, renowned as 'The Land of Spices,' is globally recognized for its cultivation and utilization of diverse varieties of spices and condiments. These vegetable-based products, devoid of any extraneous substances, are employed to enhance flavour, season dishes, and imbue them with aromatic qualities. Whether in whole or ground form, spices and condiments play a significant role in the culinary world (Shelake *et al.*, 2018). Spices, excluding leaves, can be described as the dried components of fragrant plants (Peter and Shylaja, 2012). These esoteric food additives have been utilized for thousands of years and are acknowledged for their medicinal properties in traditional medicinal practices (Nadkarni and Nadkarni, 1976).

Turmeric, a widely used spice in Asian cuisine, has a rich history of applications in the pharmaceutical, cosmetic, and food industries. In Southeast Asia, it serves as a primary spice and is also utilized in religious ceremonies, earning the name "Indian saffron." Turmeric is derived from the rhizomatous herbaceous perennial plant known as *Curcuma longa*, belonging to the ginger family Zingiberaceae. Turmeric, scientifically known as *Curcuma longa*, is indigenous to India and Asia (Prasad and Aggarwal, 2011). Curcumin, with its impressive antioxidant and anti-inflammatory properties, was found to be a genuine natural product for treating a wide array of diseases. Its antioxidant property is believed to be due to the presence of different functional groups, including methoxy, phenoxy, and carbon-carbon double bonds in its structure. Its remarkable anti-inflammatory property kept it in the limelight over the decades (Menon and Sudheer, 2007), anti-mutagenic (Jayaprakasha *et al.*, 2002), and anti-cancer effects (Bar-Sela *et al.*, 2010).

Post-harvest losses of turmeric can significantly impact farmers' incomes and food security. Turmeric, a highly valued spice and medicinal plant, is prone to various forms of wastage after being harvested. The losses occur at different stages of the post-harvest process, from harvesting and handling to storage and transportation.

Handling fresh turmeric can be challenging due to its unique characteristics and sensitivity. One common problem is staining, as turmeric's intense yellow color easily stains hands, clothing, and surfaces, requiring careful handling. Moreover, fresh

turmeric rhizomes are delicate and prone to bruising or damage during handling, reducing their shelf life and appearance.

Drying has been a prevalent method for preserving turmeric worldwide. This process entails reducing the moisture content of turmeric to a level where it remains stable and free from deterioration for an extended period. By removing moisture, the growth of bacteria, which leads to food spoilage and degradation, is prevented. Spices, including turmeric, are consistently dried and commonly used in powdered form for culinary and medicinal purposes.

Turmeric drying is of utmost importance, significantly impacting the quality, shelf life and commercial value of this valuable spice. The process reduces the moisture content, inhibiting the growth of microorganisms like mold and bacteria, ensuring its safety for consumption. Properly dried turmeric minimizes the risk of aflatoxin contamination, a harmful toxin produced by certain mold. Drying preserves turmeric's flavor, aroma, and nutritional properties by concentrating its earthy and slightly pungent taste profile and maintaining its distinct aroma. Additionally, it preserves the bioactive compound, curcumin, known for its antioxidant, anti-inflammatory, and antimicrobial properties.

Drying is the oldest method of preserving agricultural products, but it is an energy-intensive process. It is widely used worldwide for preserving farm produce by reducing water activity to a level that prevents deterioration for a specific period (Prasad *et al.*, 2006).

Sun drying, which is still prevalent in many tropical and subtropical countries, can be seen as a precursor to solar drying and an efficient way to harness solar energy (Muhlbauer, 1986; Bala, 2016; Bala, 1998; Zaman and Bala, 1989). Traditional sun drying of turmeric, for example, is heavily dependent on weather conditions and can take a long time (20 to 30 days), making it susceptible to infestation, which is unacceptable for industrial purposes (Bambirra *et al.*, 2002). The traditional open sun-drying method commonly used by rural farmers has inherent limitations, including high crop losses due to inadequate drying, fungal attacks, insect infestations, bird interference, rodent encroachment, and unpredictable weather effects (Ekechukwu, 2010).

Solar dryers, which utilize solar radiation as an energy source for drying agricultural products, have been widely implemented in tropical and subtropical regions due to their affordability and cost-effectiveness (Esper and Muhlbauer, 1998; Muller

and Muhlbauer, 2012; Udomkun *et al.*, 2020). Various types of solar dryers have been developed to overcome the limitations of direct sun drying, including cabinet solar dryers (Prasad *et al.*, 2006; Ssemwanga *et al.*, 2020), solar tunnel dryers (Janjai *et al.*, 2009; Kumar *et al.*, 2014), and greenhouse solar dryers (Janjai *et al.*, 2007; Nabnean and Nimnuan, 2020).

To reduce the moisture content of the turmeric rhizomes, a drying process is necessary to reach the desired moisture level. Two different drying methods can be employed for this purpose: solar tunnel drying and sun drying.

The experiments on drying specifically turmeric (*Curcuma longa*), were conducted using a solar tunnel dryer constructed at the Department of Renewable Energy Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. In the sun drying study, a total of 700 grams of turmeric rhizomes were evenly spread over the drying trays in a single layer. The drying process was conducted during the daytime, while data recording was not carried out during the nighttime. During the nighttime, the rhizomes were gathered and covered in the field to protect them. Weight loss readings were taken at regular intervals to monitor the drying progress. The drying process was continued until the moisture content of the turmeric rhizomes reduced to approximately 9 to 10 % on a wet basis (wb).

The experimental design for the study of turmeric rhizome drying involved fourth factors: blanching time, blanching temperature, drying method, and rhizome form. Blanching time was varied at three levels: 15, 30, and 45 minutes. The blanching temperature was set at three levels: 70 °C, 80 °C, and 90 °C. The drying method included two types: solar tunnel drying and sun drying. The rhizome forms used were sliced (4mm and 5mm) and unsliced(whole). This resulted in a $3 \times 3 \times 3$ factorial design, resulting in a total of 54 experimental units. Each experimental unit was replicated twice, bringing the total number of experimental units to 108. The experimental layout followed a Factorial Completely Randomized Design (FCRD), where the treatments were randomly assigned to the experimental units. This factorial design allowed for the investigation of the individual and interactive effects of blanching time, blanching temperature, drying method, and rhizome thickness on the drying process and the resulting quality of the turmeric rhizomes.

5.2 Conclusion

The following conclusions were drawn from the study.

- Mean value of moisture content, size, sphericity, bulk density, true density and porosity of fresh turmeric rhizomes were found to be 78.25 ± 0.703 % (wb), 30.80 ± 4.82 mm, 0.48 ± 0.07 %, 447.87 ± 10.61 kg/m³, 1115.67 ± 39.97 kg/m³ and 60.22 ± 1.02 %, respectively.
- The mean values of proximate composition, viz., total carbohydrate, true protein, total oil and total ash of raw turmeric rhizomes were found to be 9.18 ± 0.38 %, 1.41 ± 0.08 %, 0.82 ± 0.11 % and 0.71 ± 0.18 %, respectively.
- Mean value of size, sphericity, bulk density, true density and porosity of solar tunnel dried whole turmeric rhizomes were found to be 16.56 ± 2.81 mm, 0.41 ± 0.02 %, 579.15 ± 20.60 kg/m³, 1258.15 ± 61.82 kg/m³ and 54.40 %, respectively.
- Mean value of size, sphericity, bulk density, true density and porosity of sun-dried whole turmeric rhizomes were found to be 16.38 ± 2.80 mm, 0.41 ± 0.02 %, 562.09 ± 18.42 kg/m³, 1209.18 ± 49.74 kg/m³ and 53.51 %, respectively.
- The comparative analysis of turmeric drying methods, solar tunnel drying and sun drying, reveals notable distinctions in drying times under various treatment conditions. Solar tunnel drying demonstrated its efficiency with shorter drying periods, with the maximum drying time observed at 22 days for treatment B₁M₁S₃D₁ (Blanching temperature = 70°C, Blanching time = 15 min, Slice thickness = whole) and the minimum at 5 days for treatment B₃M₃S₁D₁ and B₃M₃S₂D₁ (Blanching temperature = 90°C, Blanching time = 45 min, Slice thickness = 4 mm and 5 mm, respectively).
- Sun drying generally required longer drying durations, with the maximum drying time of 40 days for treatment B₁M₁S₃D₂ (Blanching temperature = 70°C, Blanching time = 15 min, Slice thickness = whole) and the minimum at 6 days for treatment B₃M₃S₁D₂ and B₃M₃S₂D₂ (Blanching temperature = 90°C, Blanching time = 45 min, Slice thickness = 4 mm and 5 mm, respectively). These findings emphasize the advantages of solar tunnel drying over sun drying, showcasing its potential for more time-efficient turmeric drying processes across various treatment conditions.

- When turmeric was blanched at 90 °C for 45 minutes, the rate of moisture removal was faster for 4 mm, 5 mm, and whole turmeric in both solar tunnel drying and sun drying methods.
- Moisture content, total carbohydrate, true protein, total oil, total ash, total phenol, antioxidant activity, curcumin, and volatile oil of 4 mm sliced turmeric dried by solar tunnel dryer were ranged from 9.81 to 9.9 %, 42.89 to 59.03 %, 7.73 to 9.51 %, 3.01 to 4.61 %, 6.36 to 7.42 %, 2.21 to 2.97 %, 33.85 to 44.86 %, 2.17 to 4.00 % and 2.91 to 3.76 %, respectively.
- Moisture content, total carbohydrate, true protein, total oil, total ash, total phenol, antioxidant activity, curcumin, and volatile oil of 4 mm sliced turmeric dried by sun drying were ranged from 9.84 to 9.98 %, 40.06 to 52.30 %, 6.90 to 8.66 %, 2.73 to 4.01 %, 5.79 to 6.75 %, 1.94 to 2.89 %, 30.06 to 42.59 %, 1.99 to 3.70 % and 2.62 to 3.33 %, respectively.
- The optimum treatment conditions $D_1B_1M_1S_1$ (i.e., Blanching temperature-70°C, Blanching time-15 min) on the basis of retention of biochemical properties, viz., total carbohydrate, true protein, total oil, total ash, total phenol, antioxidant activity, curcumin, and volatile oil were obtained in 4 mm sliced turmeric dried by solar tunnel dryer as compared to dried by sun drying.
- Moisture content, total carbohydrate, true protein, total oil, total ash, total phenol, antioxidant activity, curcumin, and volatile oil of 5 mm sliced turmeric dried by solar tunnel dryer were ranged from 9.77 to 9.97%, 43.77 to 60.24%, 7.98 to 10.01 %, 3.07 to 4.70 %, 6.40 to 8.09 %, 2.14 to 2.88 %, 34.90 to 46.25 %, 2.25 to 4.08% and 3.00 to 3.84 %, respectively.
- Moisture content, total carbohydrate, true protein, total oil, total ash, total phenol, antioxidant activity, curcumin, and volatile oil of 5 mm sliced turmeric dried by sun drying were ranged from 9.81 to 9.96 %, 40.67 to 53.10 %, 7.27 to 9.12 %, 2.78 to 4.10 %, 5.82 to 7.36 %, 1.89 to 2.80 %, 30.99 to 43.91 %, 2.06 to 3.77 % and 2.70 to 3.40 %, respectively.
- The optimum treatment conditions $D_1B_1M_1S_1$ (i.e., Blanching temperature-70°C, Blanching time-15 min) on the basis of retention of biochemical properties, viz., total carbohydrate, true protein, total oil, total ash, total phenol, antioxidant activity, curcumin, and volatile oil were obtained in 5 mm sliced turmeric dried by solar tunnel dryer as compared to dried by sun drying.

- Moisture content, total carbohydrate, true protein, total oil, total ash, total phenol, antioxidant activity, curcumin, and volatile oil of whole turmeric rhizomes dried by solar tunnel dryer were ranged from 9.73 to 9.96 %, 46.07 to 63.41 %, 7.58 to 9.07 %, 3.20 to 4.90 %, 6.46 to 8.57 %, 2.04 to 2.77 %, 31.76 to 42.09 %, 2.37 to 4.18 % and 3.29 to 4.00 %, respectively.
- Moisture content, total carbohydrate, true protein, total oil, total ash, total phenol, antioxidant activity, curcumin, and volatile oil of whole turmeric rhizomes dried by sun drying were ranged from 9.77 to 9.97 %, 42.37 to 55.31 %, 6.56 to 8.23 %, 2.90 to 4.27 %, 5.88 to 7.80 %, 1.80 to 2.44 %, 28.20 to 39.96 %, 2.20 to 3.91 % and 3.04 to 3.55 %, respectively.
- The optimum treatment conditions $D_1B_1M_1S_1$ (i.e., Blanching temperature-70°C, Blanching time-15 min) on the basis of retention of biochemical properties, viz., total carbohydrate, true protein, total oil, total ash, total phenol, antioxidant activity, curcumin, and volatile oil were obtained in whole turmeric dried by solar tunnel dryer as compared to dried by sun drying.
- On the basis of biochemical parameters of solar tunnel dried powder, highest retention of curcumin (4.18 %), volatile oil (4.00 %), total carbohydrate (63.41 %), total oil (4.90 %) and total ash (8.57 %) were obtained in whole turmeric rhizomes.
- On the basis of biochemical parameters of solar tunnel dried powder, highest retention of antioxidant activity (46.25 %), true protein (10.01 %) was found in 5 mm turmeric thickness, whereas highest retention of total phenol (2.97 %) was found in 4 mm turmeric thickness.
- Solar tunnel drying method is an effective alternative to traditional open sun drying, where retention of curcumin, volatile oil, total oil, total phenol, antioxidant activity total carbohydrate and true protein was high, with less drying times.
- From the present investigation, on the basis of biochemical parameters it is concluded that the best quality turmeric powder is prepared by solar tunnel dried whole turmeric rhizomes blanched at 70°C for 15 min.
- "A minimal post-harvest loss of turmeric rhizomes occurred during the drying process using the solar tunnel dryer. In contrast, there was an 8.20% post-harvest loss observed with the traditional sun drying method."

- The loss of 1.7 kg in sun-drying represents 8.20% of the final recovery, which is 20.70 kg in the sun-dried method.
- The recovery level of dried turmeric rhizomes was higher in the Solar Tunnel Dryer (22.40 kg/q) as compared to traditional sun drying method (20.70 kg/q) in terms of quantity as 1.70 kg/q and in terms economics return as Rs. 561.00 per 100 kg of turmeric rhizomes. In other words, farmers of Saurashtra region will gain additional benefits of Rs. 2805 per batch of 500 kg of fresh turmeric rhizomes by adopting solar tunnel dryer.
- So, producer of Saurashtra region will get benefited by using solar tunnel dryer in terms if minimizing post-harvest loss of turmeric rhizomes (8.2 %) as well as good returns of their final product (Rs. 561.00/q) as compared to traditional sun drying method.

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APPENDIX – A1

Size (Geometric mean diameter) and sphericity of fresh turmeric rhizomes (at moisture content of 78.25 % wb)

| Sr. No. | Length (mm) | Breadth (mm) | Thickness (mm) | Size (mm) | Sphericity |
|---------|-------------|--------------|----------------|-----------|------------|
| 1 | 71.35 | 19.65 | 20.75 | 30.76 | 0.43 |
| 2 | 65.31 | 29.83 | 26.72 | 37.34 | 0.57 |
| 3 | 65.11 | 21.99 | 21.41 | 31.30 | 0.48 |
| 4 | 59.53 | 21.21 | 19.88 | 29.28 | 0.49 |
| 5 | 34.18 | 18.70 | 16.79 | 22.06 | 0.65 |
| 6 | 69.50 | 24.37 | 23.55 | 34.17 | 0.49 |
| 7 | 56.34 | 18.98 | 20.85 | 28.15 | 0.50 |
| 8 | 46.63 | 15.08 | 15.74 | 22.28 | 0.48 |
| 9 | 72.01 | 19.51 | 20.89 | 30.85 | 0.43 |
| 10 | 43.99 | 20.75 | 21.82 | 27.10 | 0.62 |
| 11 | 77.54 | 20.52 | 21.03 | 32.23 | 0.42 |
| 12 | 82.79 | 21.71 | 21.90 | 34.02 | 0.41 |
| 13 | 36.38 | 18.99 | 18.64 | 23.44 | 0.64 |
| 14 | 57.69 | 21.35 | 20.61 | 29.39 | 0.51 |
| 15 | 58.80 | 15.79 | 17.05 | 25.11 | 0.43 |
| 16 | 55.63 | 17.53 | 15.64 | 24.80 | 0.45 |
| 17 | 94.46 | 22.67 | 24.21 | 37.29 | 0.39 |
| 18 | 66.20 | 22.91 | 23.76 | 33.03 | 0.50 |
| 19 | 65.11 | 21.59 | 21.92 | 31.35 | 0.48 |

| | | | | | |
|-----------|-------|-------|-------|-------|------|
| 20 | 94.02 | 24.46 | 24.45 | 38.31 | 0.41 |
| 21 | 68.58 | 21.11 | 20.78 | 31.10 | 0.45 |
| 22 | 46.04 | 16.10 | 16.81 | 23.18 | 0.50 |
| 23 | 37.34 | 13.58 | 12.53 | 18.52 | 0.50 |
| 24 | 83.44 | 22.99 | 20.32 | 33.91 | 0.41 |
| 25 | 73.76 | 21.61 | 23.29 | 33.36 | 0.45 |
| 26 | 50.20 | 21.72 | 22.48 | 29.05 | 0.58 |
| 27 | 60.95 | 20.49 | 22.07 | 30.20 | 0.50 |
| 28 | 67.01 | 21.66 | 21.55 | 31.51 | 0.47 |
| 29 | 72.16 | 20.70 | 22.87 | 32.44 | 0.45 |
| 30 | 56.22 | 19.66 | 21.05 | 28.55 | 0.51 |

| Parameter | Mean | SD |
|-------------------|--------------|-------------|
| Length (mm) | 65.11 | 15.45 |
| Breadth (mm) | 20.93 | 3.122 |
| Thickness (mm) | 21.04 | 3.041 |
| Size (mm) | 30.80 | 4.82 |
| Sphericity | 0.48 | 0.07 |

APPENDIX – A2

Size (Geometric mean diameter) and sphericity of solar tunnel dried turmeric rhizomes

| Sr. No. | Treatments | Moisture content, % (d.b.) | Length (mm) | Breadth (mm) | Thickness (mm) | Size (mm) | Sphericity |
|---------|--|----------------------------|-------------|--------------|----------------|-----------|------------|
| 1 | T ₃ (B ₁ M ₁ S ₃ D ₁) | 7.97 | 42.59 | 11.87 | 10.95 | 17.69 | 0.415 |
| 2 | T ₆ (B ₁ M ₂ S ₃ D ₁) | 8.79 | 35.18 | 8.88 | 8.18 | 13.67 | 0.389 |
| 3 | T ₉ (B ₁ M ₃ S ₃ D ₁) | 8.89 | 33.84 | 7.11 | 6.85 | 11.81 | 0.349 |
| 4 | T ₁₂ (B ₂ M ₁ S ₃ D ₁) | 8.42 | 45.98 | 13.06 | 12.12 | 19.38 | 0.421 |
| 5 | T ₁₅ (B ₂ M ₂ S ₃ D ₁) | 8.97 | 39.87 | 10.46 | 9.49 | 15.82 | 0.397 |
| 6 | T ₁₈ (B ₂ M ₃ S ₃ D ₁) | 8.09 | 37.49 | 9.86 | 9.05 | 14.95 | 0.399 |
| 7 | T ₂₁ (B ₃ M ₁ S ₃ D ₁) | 8.74 | 49.55 | 13.85 | 12.74 | 20.60 | 0.416 |
| 8 | T ₂₄ (B ₃ M ₂ S ₃ D ₁) | 8.56 | 43.56 | 12.46 | 11.58 | 18.45 | 0.424 |
| 9 | T ₂₇ (B ₃ M ₃ S ₃ D ₁) | 7.88 | 40.16 | 11.13 | 10.15 | 16.56 | 0.412 |

| Parameter | Mean | SD |
|-------------------|--------------|-------------|
| Length (mm) | 40.16 | 5.08 |
| Breadth (mm) | 11.13 | 2.13 |
| Thickness (mm) | 10.15 | 1.93 |
| Size (mm) | 16.56 | 2.81 |
| Sphericity | 0.41 | 0.02 |

APPENDIX – A3

Size (Geometric mean diameter) and sphericity of solar tunnel dried turmeric rhizomes

| Sr. No. | Treatments | Moisture content, % (db) | Length (mm) | Breadth (mm) | Thickness (mm) | Size (mm) | Sphericity |
|---------|--|--------------------------|-------------|--------------|----------------|-----------|------------|
| 1 | T ₃ (B ₁ M ₁ S ₃ D ₂) | 7.25 | 42.16 | 11.75 | 10.842 | 17.51 | 0.415 |
| 2 | T ₆ (B ₁ M ₂ S ₃ D ₂) | 8.00 | 34.85 | 8.55 | 8.100 | 13.41 | 0.385 |
| 3 | T ₉ (B ₁ M ₃ S ₃ D ₂) | 8.08 | 33.50 | 7.04 | 6.755 | 11.68 | 0.349 |
| 4 | T ₁₂ (B ₂ M ₁ S ₃ D ₂) | 7.66 | 45.49 | 12.85 | 11.998 | 19.14 | 0.421 |
| 5 | T ₁₅ (B ₂ M ₂ S ₃ D ₂) | 8.16 | 39.47 | 10.36 | 9.393 | 15.66 | 0.397 |
| 6 | T ₁₈ (B ₂ M ₃ S ₃ D ₂) | 7.36 | 37.11 | 9.76 | 8.948 | 14.80 | 0.399 |
| 7 | T ₂₁ (B ₃ M ₁ S ₃ D ₂) | 7.96 | 49.12 | 13.70 | 12.611 | 20.39 | 0.415 |
| 8 | T ₂₄ (B ₃ M ₂ S ₃ D ₂) | 7.78 | 43.12 | 12.33 | 11.468 | 18.27 | 0.424 |
| 9 | T ₂₇ (B ₃ M ₃ S ₃ D ₂) | 7.17 | 39.76 | 11.02 | 10.036 | 16.38 | 0.412 |

| Parameter | Mean | SD |
|----------------|-------|------|
| Length (mm) | 39.76 | 5.03 |
| Breadth (mm) | 11.02 | 2.13 |
| Thickness (mm) | 10.04 | 1.91 |
| Size (mm) | 16.38 | 2.80 |
| Sphericity | 0.41 | 0.02 |

APPENDIX – A4

Variation in moisture content of blanched turmeric

| Sr. No. | Moisture content after blanching % (wb) | | | | | | | |
|-----------|--|-------|-------|-------|--|-------|-------|-------|
| | Solar Tunnel Drying | | | | Sun Drying | | | |
| | Treatments | R1 | R2 | Mean | Treatments | R1 | R2 | Mean |
| 1 | T ₁ (B ₁ M ₁ S ₁ D ₁) | 80.58 | 79.84 | 80.21 | T ₁ (B ₁ M ₁ S ₁ D ₂) | 81.50 | 79.39 | 80.45 |
| 2 | T ₂ (B ₁ M ₁ S ₂ D ₁) | 80.76 | 79.34 | 80.05 | T ₂ (B ₁ M ₁ S ₂ D ₂) | 80.44 | 79.75 | 80.10 |
| 3 | T ₃ (B ₁ M ₁ S ₃ D ₁) | 80.32 | 80.37 | 80.35 | T ₃ (B ₁ M ₁ S ₃ D ₂) | 81.03 | 80.54 | 80.78 |
| 4 | T ₄ (B ₁ M ₂ S ₁ D ₁) | 80.65 | 79.64 | 80.14 | T ₄ (B ₁ M ₂ S ₁ D ₂) | 79.34 | 80.68 | 80.01 |
| 5 | T ₅ (B ₁ M ₂ S ₂ D ₁) | 79.35 | 80.94 | 80.15 | T ₅ (B ₁ M ₂ S ₂ D ₂) | 79.34 | 81.01 | 80.17 |
| 6 | T ₆ (B ₁ M ₂ S ₃ D ₁) | 80.83 | 79.54 | 80.19 | T ₆ (B ₁ M ₂ S ₃ D ₂) | 79.65 | 81.76 | 80.71 |
| 7 | T ₇ (B ₁ M ₃ S ₁ D ₁) | 81.11 | 79.25 | 80.18 | T ₇ (B ₁ M ₃ S ₁ D ₂) | 79.31 | 80.88 | 80.10 |
| 8 | T ₈ (B ₁ M ₃ S ₂ D ₁) | 80.86 | 79.48 | 80.17 | T ₈ (B ₁ M ₃ S ₂ D ₂) | 81.21 | 79.75 | 80.48 |
| 9 | T ₉ (B ₁ M ₃ S ₃ D ₁) | 81.95 | 79.43 | 80.69 | T ₉ (B ₁ M ₃ S ₃ D ₂) | 81.79 | 79.31 | 80.55 |
| 10 | T ₁₀ (B ₂ M ₁ S ₁ D ₁) | 80.62 | 79.46 | 80.04 | T ₁₀ (B ₂ M ₁ S ₁ D ₂) | 79.48 | 80.77 | 80.13 |
| 11 | T ₁₁ (B ₂ M ₁ S ₂ D ₁) | 81.61 | 79.13 | 80.37 | T ₁₁ (B ₂ M ₁ S ₂ D ₂) | 79.25 | 80.86 | 80.05 |

| | | | | | | | | |
|-----------|--|-------|-------|-------|--|-------|-------|-------|
| 12 | T ₁₂ (B ₂ M ₁ S ₃ D ₁) | 79.64 | 80.41 | 80.02 | T ₁₂ (B ₂ M ₁ S ₃ D ₂) | 81.00 | 79.78 | 80.39 |
| 13 | T ₁₃ (B ₂ M ₂ S ₁ D ₁) | 79.66 | 80.52 | 80.09 | T ₁₃ (B ₂ M ₂ S ₁ D ₂) | 80.09 | 79.96 | 80.02 |
| 14 | T ₁₄ (B ₂ M ₂ S ₂ D ₁) | 80.52 | 79.82 | 80.17 | T ₁₄ (B ₂ M ₂ S ₂ D ₂) | 80.59 | 79.51 | 80.05 |
| 15 | T ₁₅ (B ₂ M ₂ S ₃ D ₁) | 80.77 | 79.31 | 80.04 | T ₁₅ (B ₂ M ₂ S ₃ D ₂) | 79.66 | 80.60 | 80.13 |
| 16 | T ₁₆ (B ₂ M ₃ S ₁ D ₁) | 79.74 | 80.36 | 80.05 | T ₁₆ (B ₂ M ₃ S ₁ D ₂) | 80.96 | 79.15 | 80.05 |
| 17 | T ₁₇ (B ₂ M ₃ S ₂ D ₁) | 80.61 | 79.65 | 80.13 | T ₁₇ (B ₂ M ₃ S ₂ D ₂) | 79.50 | 80.53 | 80.01 |
| 18 | T ₁₈ (B ₂ M ₃ S ₃ D ₁) | 80.48 | 79.66 | 80.07 | T ₁₈ (B ₂ M ₃ S ₃ D ₂) | 79.59 | 80.65 | 80.12 |
| 19 | T ₁₉ (B ₃ M ₁ S ₁ D ₁) | 79.65 | 81.47 | 80.56 | T ₁₉ (B ₃ M ₁ S ₁ D ₂) | 80.90 | 79.52 | 80.21 |
| 20 | T ₂₀ (B ₃ M ₁ S ₂ D ₁) | 80.33 | 79.86 | 80.10 | T ₂₀ (B ₃ M ₁ S ₂ D ₂) | 79.86 | 80.54 | 80.20 |
| 21 | T ₂₁ (B ₃ M ₁ S ₃ D ₁) | 80.19 | 79.96 | 80.08 | T ₂₁ (B ₃ M ₁ S ₃ D ₂) | 80.05 | 80.14 | 80.10 |
| 22 | T ₂₂ (B ₃ M ₂ S ₁ D ₁) | 79.65 | 80.61 | 80.13 | T ₂₂ (B ₃ M ₂ S ₁ D ₂) | 80.58 | 79.61 | 80.10 |
| 23 | T ₂₃ (B ₃ M ₂ S ₂ D ₁) | 79.88 | 80.22 | 80.05 | T ₂₃ (B ₃ M ₂ S ₂ D ₂) | 79.82 | 80.52 | 80.17 |
| 24 | T ₂₄ (B ₃ M ₂ S ₃ D ₁) | 79.46 | 80.54 | 80.00 | T ₂₄ (B ₃ M ₂ S ₃ D ₂) | 85.69 | 74.39 | 80.04 |
| 25 | T ₂₅ (B ₃ M ₃ S ₁ D ₁) | 80.98 | 79.14 | 80.06 | T ₂₅ (B ₃ M ₃ S ₁ D ₂) | 79.20 | 80.90 | 80.05 |
| 26 | T ₂₆ (B ₃ M ₃ S ₂ D ₁) | 79.35 | 80.84 | 80.10 | T ₂₆ (B ₃ M ₃ S ₂ D ₂) | 79.97 | 80.45 | 80.21 |
| 27 | T ₂₇ (B ₃ M ₃ S ₃ D ₁) | 79.69 | 80.39 | 80.04 | T ₂₇ (B ₃ M ₃ S ₃ D ₂) | 79.36 | 80.64 | 80.00 |

APPENDIX – B1

Moisture content of solar tunnel-dried turmeric at 70 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture content (% db) | | | | | | | | | |
|-------------------------|--|--|--|--|--|--|--|--|--|
| Day | T ₁ (B ₁ M ₁ S ₁ D ₁) | T ₂ (B ₁ M ₁ S ₂ D ₁) | T ₃ (B ₁ M ₁ S ₃ D ₁) | T ₄ (B ₁ M ₂ S ₁ D ₁) | T ₅ (B ₁ M ₂ S ₂ D ₁) | T ₆ (B ₁ M ₂ S ₃ D ₁) | T ₇ (B ₁ M ₃ S ₁ D ₁) | T ₈ (B ₁ M ₃ S ₂ D ₁) | T ₉ (B ₁ M ₃ S ₃ D ₁) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 405.3 | 401.3 | 408.8 | 403.6 | 403.7 | 404.7 | 404.5 | 404.3 | 417.9 |
| 1 | 135.3 | 128.1 | 239.2 | 125.2 | 120.7 | 236.8 | 121.7 | 131.3 | 209.3 |
| 2 | 69.3 | 80.3 | 119.7 | 94.9 | 86.3 | 118.5 | 90.6 | 101.7 | 104.4 |
| 3 | 49.3 | 45.7 | 90.3 | 45.9 | 60.0 | 89.4 | 50.3 | 65.2 | 76.9 |
| 4 | 24.4 | 27.3 | 65.2 | 29.0 | 32.7 | 64.6 | 24.9 | 27.4 | 56.1 |
| 5 | 16.3 | 21.3 | 49.0 | 20.0 | 26.0 | 48.5 | 18.0 | 17.3 | 42.1 |
| 6 | 15.4 | 15.3 | 37.2 | 14.3 | 15.3 | 36.8 | 9.9 | 9.8 | 32.8 |
| 7 | 9.9 | 10.0 | 31.3 | 9.9 | 9.8 | 31.0 | | | 27.4 |
| 8 | | | 27.7 | | | 27.4 | | | 23.0 |
| 9 | | | 25.7 | | | 25.4 | | | 21.8 |
| 10 | | | 21.5 | | | 21.3 | | | 19.1 |
| 11 | | | 18.3 | | | 18.1 | | | 15.8 |
| 12 | | | 14.9 | | | 14.7 | | | 13.4 |
| 14 | | | 13.5 | | | 13.3 | | | 11.6 |
| 16 | | | 12.5 | | | 12.4 | | | 9.9 |
| 18 | | | 11.8 | | | 11.7 | | | 9.7 |
| 20 | | | 10.7 | | | 9.9 | | | |
| 22 | | | 10.6 | | | | | | |

APPENDIX – B2

Drying rate per given time interval of solar tunnel-dried turmeric at 70 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Drying rate per given time interval (g of water / 100 g of dry matter)/day | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Day | T₁ (B₁M₁S₁D₁) | T₂ (B₁M₁S₂D₁) | T₃ (B₁M₁S₃D₁) | T₄ (B₁M₂S₁D₁) | T₅ (B₁M₂S₂D₁) | T₆ (B₁M₂S₃D₁) | T₇ (B₁M₃S₁D₁) | T₈ (B₁M₃S₂D₁) | T₉ (B₁M₃S₃D₁) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0.562 | 0.569 | 0.353 | 0.580 | 0.590 | 0.350 | 0.589 | 0.569 | 0.435 |
| 2 | 0.138 | 0.100 | 0.249 | 0.063 | 0.072 | 0.247 | 0.065 | 0.062 | 0.218 |
| 3 | 0.042 | 0.072 | 0.061 | 0.102 | 0.055 | 0.061 | 0.084 | 0.076 | 0.057 |
| 4 | 0.052 | 0.038 | 0.052 | 0.035 | 0.057 | 0.052 | 0.053 | 0.079 | 0.043 |
| 5 | 0.017 | 0.013 | 0.034 | 0.019 | 0.014 | 0.034 | 0.014 | 0.021 | 0.029 |
| 6 | 0.002 | 0.013 | 0.025 | 0.012 | 0.022 | 0.024 | 0.017 | 0.016 | 0.019 |
| 7 | 0.011 | 0.011 | 0.012 | 0.009 | 0.011 | 0.012 | | | 0.011 |
| 8 | | | 0.008 | | | 0.007 | | | 0.009 |
| 10 | | | 0.009 | | | 0.009 | | | 0.006 |
| 11 | | | 0.007 | | | 0.007 | | | 0.007 |
| 12 | | | 0.007 | | | 0.007 | | | 0.005 |
| 13 | | | 0.002 | | | 0.002 | | | 0.003 |
| 14 | | | 0.001 | | | 0.001 | | | 0.001 |
| 16 | | | 0.001 | | | 0.001 | | | 0.001 |
| 18 | | | 0.001 | | | 0.001 | | | 0.000 |
| 20 | | | 0.003 | | | 0.003 | | | |
| 22 | | | 0.000 | | | | | | |

APPENDIX – B3

Moisture ratio of solar tunnel-dried turmeric at 70 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture ratio | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|---|
| Day | T₁ (B₁M₁S₁D₁) | T₂ (B₁M₁S₂D₁) | T₃ (B₁M₁S₃D₁) | T₄ (B₁M₂S₁D₁) | T₅ (B₁M₂S₂D₁) | T₆ (B₁M₂S₃D₁) | T₇ (B₁M₃S₁D₁) | T₈ (B₁M₃S₂D₁) | T₉ (B₁M₃S₃D₁) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 1 | 1.00 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0.317 | 0.302 | 0.574 | 0.293 | 0.282 | 0.575 | 0.283 | 0.308 | 0.489 |
| 2 | 0.150 | 0.180 | 0.274 | 0.216 | 0.194 | 0.275 | 0.204 | 0.233 | 0.232 |
| 3 | 0.100 | 0.091 | 0.200 | 0.091 | 0.127 | 0.201 | 0.102 | 0.140 | 0.165 |
| 4 | 0.037 | 0.044 | 0.137 | 0.049 | 0.058 | 0.139 | 0.038 | 0.045 | 0.114 |
| 5 | 0.016 | 0.029 | 0.096 | 0.026 | 0.041 | 0.098 | 0.020 | 0.019 | 0.079 |
| 6 | 0.014 | 0.013 | 0.067 | 0.011 | 0.014 | 0.068 | 0.000 | 0.000 | 0.057 |
| 7 | 0.000 | 0.000 | 0.052 | 0.000 | 0.000 | 0.053 | | | 0.043 |
| 8 | | | 0.043 | | | 0.044 | | | 0.033 |
| 10 | | | 0.027 | | | 0.029 | | | 0.023 |
| 12 | | | 0.011 | | | 0.012 | | | 0.009 |
| 13 | | | 0.008 | | | 0.010 | | | 0.006 |
| 14 | | | 0.007 | | | 0.009 | | | 0.005 |
| 15 | | | 0.006 | | | 0.008 | | | 0.002 |
| 16 | | | 0.005 | | | 0.006 | | | 0.001 |
| 18 | | | 0.003 | | | 0.005 | | | 0.000 |
| 20 | | | 0.002 | | | 0.000 | | | 0.000 |
| 22 | | | 0.000 | | | 0.000 | | | |

APPENDIX – C1

Moisture content of solar tunnel-dried turmeric at 80 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture content (% d. b.) | | | | | | | | | |
|-----------------------------------|--|--|--|--|--|--|--|--|--|
| Day | T₁₀ (B₂M₁S₁D₁) | T₁₁ (B₂M₁S₂D₁) | T₁₂ (B₂M₁S₃D₁) | T₁₃ (B₂M₂S₁D₁) | T₁₄ (B₂M₂S₂D₁) | T₁₅ (B₂M₂S₃D₁) | T₁₆ (B₂M₃S₁D₁) | T₁₇ (B₂M₃S₂D₁) | T₁₈ (B₂M₃S₃D₁) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 401.0 | 409.4 | 400.6 | 402.2 | 404.3 | 401.0 | 401.3 | 403.3 | 401.7 |
| 1 | 129.0 | 131.6 | 234.4 | 117.3 | 126.3 | 232.1 | 104.3 | 110.7 | 229.8 |
| 2 | 72.3 | 75.3 | 117.3 | 80.4 | 99.0 | 116.1 | 37.4 | 42.7 | 114.9 |
| 3 | 56.6 | 41.1 | 88.5 | 47.7 | 60.9 | 87.6 | 18.3 | 20.4 | 86.7 |
| 4 | 30.3 | 28.1 | 63.9 | 23.0 | 26.0 | 63.3 | 12.4 | 14.4 | 62.7 |
| 5 | 21.3 | 20.4 | 48.0 | 16.3 | 18.5 | 47.5 | 9.9 | 9.8 | 47.0 |
| 6 | 14.3 | 14.0 | 36.4 | 10.0 | 9.8 | 36.1 | | | 35.7 |
| 7 | 10.0 | 9.8 | 30.6 | | | 30.3 | | | 30.0 |
| 8 | | | 27.1 | | | 26.8 | | | 26.6 |
| 9 | | | 25.2 | | | 24.9 | | | 24.7 |
| 10 | | | 21.1 | | | 20.9 | | | 20.7 |
| 12 | | | 14.6 | | | 14.5 | | | 14.3 |
| 14 | | | 13.2 | | | 13.1 | | | 12.5 |
| 16 | | | 12.3 | | | 12.2 | | | 10.3 |
| 18 | | | 11.6 | | | 10.7 | | | |
| 21 | | | 9.9 | | | | | | |

APPENDIX – C2

Drying rate per given time interval of solar tunnel-dried turmeric at 80 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Drying rate per given time interval (g of water / 100 g of dry matter)/day | | | | | | | | | |
|---|--|--|--|--|--|--|--|--|--|
| Day | T₁₀ (B₂M₁S₁D₁) | T₁₁ (B₂M₁S₂D₁) | T₁₂ (B₂M₁S₃D₁) | T₁₃ (B₂M₂S₁D₁) | T₁₄ (B₂M₂S₂D₁) | T₁₅ (B₂M₂S₃D₁) | T₁₆ (B₂M₃S₁D₁) | T₁₇ (B₂M₃S₂D₁) | T₁₈ (B₂M₃S₃D₁) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0.567 | 0.579 | 0.346 | 0.594 | 0.579 | 0.352 | 0.619 | 0.610 | 0.358 |
| 2 | 0.118 | 0.117 | 0.244 | 0.077 | 0.057 | 0.242 | 0.139 | 0.142 | 0.239 |
| 3 | 0.033 | 0.071 | 0.060 | 0.068 | 0.079 | 0.059 | 0.040 | 0.046 | 0.059 |
| 4 | 0.055 | 0.027 | 0.051 | 0.051 | 0.073 | 0.051 | 0.012 | 0.013 | 0.050 |
| 5 | 0.019 | 0.016 | 0.033 | 0.014 | 0.015 | 0.033 | 0.005 | 0.009 | 0.033 |
| 6 | 0.015 | 0.013 | 0.024 | 0.013 | 0.018 | 0.024 | | | 0.024 |
| 7 | 0.009 | 0.009 | 0.012 | | | 0.012 | | | 0.012 |
| 8 | | | 0.007 | | | 0.007 | | | 0.007 |
| 9 | | | 0.004 | | | 0.004 | | | 0.004 |
| 10 | | | 0.009 | | | 0.008 | | | 0.008 |
| 11 | | | 0.007 | | | 0.007 | | | 0.007 |
| 12 | | | 0.007 | | | 0.007 | | | 0.007 |
| 13 | | | 0.002 | | | 0.002 | | | 0.003 |
| 14 | | | 0.001 | | | 0.001 | | | 0.001 |
| 16 | | | 0.001 | | | 0.001 | | | 0.003 |
| 18 | | | 0.000 | | | 0.001 | | | |
| 21 | | | 0.000 | | | | | | |

APPENDIX – C3

Moisture ratio of solar tunnel-dried turmeric at 80 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture ratio | | | | | | | | | |
|-----------------------|--|--|--|--|--|--|--|--|--|
| Day | T₁₀ (B₂M₁S₁D₁) | T₁₁ (B₂M₁S₂D₁) | T₁₂ (B₂M₁S₃D₁) | T₁₃ (B₂M₂S₁D₁) | T₁₄ (B₂M₂S₂D₁) | T₁₅ (B₂M₂S₃D₁) | T₁₆ (B₂M₃S₁D₁) | T₁₇ (B₂M₃S₂D₁) | T₁₈ (B₂M₃S₃D₁) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.975 | 0.976 | 1.000 |
| 1 | 0.304 | 0.305 | 0.575 | 0.274 | 0.295 | 0.568 | 0.260 | 0.274 | 0.561 |
| 2 | 0.159 | 0.164 | 0.275 | 0.179 | 0.226 | 0.271 | 0.093 | 0.106 | 0.268 |
| 3 | 0.119 | 0.078 | 0.201 | 0.096 | 0.129 | 0.198 | 0.046 | 0.051 | 0.196 |
| 4 | 0.052 | 0.046 | 0.138 | 0.033 | 0.041 | 0.136 | 0.031 | 0.036 | 0.135 |
| 5 | 0.029 | 0.027 | 0.097 | 0.016 | 0.022 | 0.096 | 0.025 | 0.024 | 0.095 |
| 6 | 0.011 | 0.011 | 0.068 | 0.000 | 0.000 | 0.067 | | | 0.066 |
| 7 | 0.000 | 0.000 | 0.053 | | | 0.052 | | | 0.051 |
| 8 | | | 0.044 | | | 0.043 | | | 0.043 |
| 9 | | | 0.039 | | | 0.038 | | | 0.038 |
| 10 | | | 0.029 | | | 0.028 | | | 0.028 |
| 12 | | | 0.012 | | | 0.011 | | | 0.011 |
| 14 | | | 0.008 | | | 0.008 | | | 0.007 |
| 16 | | | 0.006 | | | 0.006 | | | 0.001 |
| 18 | | | 0.004 | | | 0.002 | | | |
| 21 | | | 0.000 | | | | | | |

APPENDIX – D1

Moisture content of solar tunnel-dried turmeric at 90 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture content (% d. b.) | | | | | | | | | |
|-----------------------------------|--|--|--|--|--|--|--|--|--|
| Day | T₁₉ (B₃M₁S₁D₁) | T₂₀ (B₃M₁S₂D₁) | T₂₁ (B₃M₁S₃D₁) | T₂₂ (B₃M₂S₁D₁) | T₂₃ (B₃M₂S₂D₁) | T₂₄ (B₃M₂S₃D₁) | T₂₅ (B₃M₃S₁D₁) | T₂₆ (B₃M₃S₂D₁) | T₂₇ (B₃M₃S₃D₁) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 414.4 | 402.4 | 401.9 | 403.3 | 401.3 | 400.0 | 401.5 | 402.4 | 401.0 |
| 1 | 123.9 | 127.7 | 227.5 | 113.3 | 113.3 | 225.2 | 101.3 | 107.3 | 222.9 |
| 2 | 96.3 | 69.1 | 113.8 | 44.7 | 45.2 | 112.7 | 35.3 | 41.0 | 111.5 |
| 3 | 38.7 | 39.9 | 85.8 | 21.7 | 22.3 | 85.0 | 17.3 | 19.3 | 84.1 |
| 4 | 23.2 | 23.9 | 62.0 | 15.2 | 15.2 | 61.4 | 11.3 | 13.3 | 60.8 |
| 5 | 15.5 | 16.0 | 46.6 | 10.0 | 10.0 | 46.1 | 10.0 | 10.0 | 45.6 |
| 6 | 9.8 | 9.9 | 35.3 | | | 35.0 | | | 34.6 |
| 7 | | | 29.7 | | | 29.4 | | | 29.1 |
| 8 | | | 26.3 | | | 26.0 | | | 25.8 |
| 9 | | | 24.4 | | | 24.2 | | | 24.0 |
| 10 | | | 20.5 | | | 20.3 | | | 20.1 |
| 12 | | | 14.2 | | | 14.0 | | | 13.9 |
| 14 | | | 12.4 | | | 12.3 | | | 11.5 |
| 16 | | | 11.0 | | | 10.9 | | | 10.0 |
| 18 | | | 10.1 | | | 10.0 | | | |
| 20 | | | 9.9 | | | | | | |

APPENDIX – D2

Drying rate per given time interval of solar tunnel-dried turmeric at 90 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Drying rate per given time interval (g of water / 100 g of dry matter)/day | | | | | | | | | |
|---|--|--|--|--|--|--|--|--|--|
| Day | T₁₉ (B₃M₁S₁D₁) | T₂₀ (B₃M₁S₂D₁) | T₂₁ (B₃M₁S₃D₁) | T₂₂ (B₃M₂S₁D₁) | T₂₃ (B₃M₂S₂D₁) | T₂₄ (B₃M₂S₃D₁) | T₂₅ (B₃M₃S₁D₁) | T₂₆ (B₃M₃S₂D₁) | T₂₇ (B₃M₃S₃D₁) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 0.605 | 0.572 | 0.363 | 0.604 | 0.600 | 0.364 | 0.625 | 0.615 | 0.371 |
| 2 | 0.058 | 0.122 | 0.237 | 0.143 | 0.142 | 0.234 | 0.138 | 0.138 | 0.232 |
| 3 | 0.120 | 0.061 | 0.058 | 0.048 | 0.048 | 0.058 | 0.037 | 0.045 | 0.057 |
| 4 | 0.032 | 0.033 | 0.050 | 0.013 | 0.015 | 0.049 | 0.013 | 0.013 | 0.049 |
| 5 | 0.016 | 0.016 | 0.032 | 0.011 | 0.011 | 0.032 | 0.003 | 0.007 | 0.032 |
| 6 | 0.012 | 0.013 | 0.023 | | | 0.023 | | | 0.023 |
| 7 | | | 0.012 | | | 0.012 | | | 0.011 |
| 8 | | | 0.007 | | | 0.007 | | | 0.007 |
| 9 | | | 0.004 | | | 0.004 | | | 0.004 |
| 10 | | | 0.008 | | | 0.008 | | | 0.008 |
| 11 | | | 0.006 | | | 0.006 | | | 0.006 |
| 12 | | | 0.007 | | | 0.007 | | | 0.007 |
| 13 | | | 0.003 | | | 0.003 | | | 0.003 |
| 14 | | | 0.001 | | | 0.001 | | | 0.002 |
| 15 | | | 0.002 | | | 0.002 | | | 0.002 |
| 16 | | | 0.001 | | | 0.001 | | | 0.001 |
| 18 | | | 0.001 | | | 0.001 | | | |

APPENDIX – D3

Moisture ratio of solar tunnel-dried turmeric at 90 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture ratio | | | | | | | | | |
|-----------------------|--|--|--|--|--|--|--|--|--|
| Day | T₁₉ (B₃M₁S₁D₁) | T₂₀ (B₃M₁S₂D₁) | T₂₁ (B₃M₁S₃D₁) | T₂₂ (B₃M₂S₁D₁) | T₂₃ (B₃M₂S₂D₁) | T₂₄ (B₃M₂S₃D₁) | T₂₅ (B₃M₃S₁D₁) | T₂₆ (B₃M₃S₂D₁) | T₂₇ (B₃M₃S₃D₁) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 1.000 | 1.000 | 1.000 | 0.975 | 0.975 | 1.000 | 0.975 | 0.975 | 1.000 |
| 1 | 0.282 | 0.300 | 0.555 | 0.281 | 0.282 | 0.552 | 0.252 | 0.267 | 0.545 |
| 2 | 0.214 | 0.151 | 0.265 | 0.111 | 0.113 | 0.263 | 0.088 | 0.102 | 0.260 |
| 3 | 0.071 | 0.077 | 0.194 | 0.054 | 0.056 | 0.192 | 0.043 | 0.048 | 0.190 |
| 4 | 0.033 | 0.036 | 0.133 | 0.038 | 0.038 | 0.132 | 0.028 | 0.033 | 0.130 |
| 5 | 0.014 | 0.016 | 0.093 | 0.025 | 0.025 | 0.093 | 0.025 | 0.025 | 0.091 |
| 6 | 0.000 | 0.000 | 0.065 | | | 0.064 | | | 0.063 |
| 7 | | | 0.051 | | | 0.050 | | | 0.049 |
| 8 | | | 0.042 | | | 0.041 | | | 0.040 |
| 9 | | | 0.037 | | | 0.036 | | | 0.036 |
| 10 | | | 0.027 | | | 0.026 | | | 0.026 |
| 12 | | | 0.011 | | | 0.010 | | | 0.010 |
| 14 | | | 0.006 | | | 0.006 | | | 0.004 |
| 16 | | | 0.003 | | | 0.002 | | | 0.000 |
| 18 | | | 0.001 | | | 0.000 | | | |

APPENDIX – E1

Moisture content of sun-dried turmeric at 70 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture content (% d. b.) | | | | | | | | | |
|----------------------------|--|--|--|--|--|--|--|--|--|
| Day | T ₁ (B ₁ M ₁ S ₁ D ₂) | T ₂ (B ₁ M ₁ S ₂ D ₂) | T ₃ (B ₁ M ₁ S ₃ D ₂) | T ₄ (B ₁ M ₂ S ₁ D ₂) | T ₅ (B ₁ M ₂ S ₂ D ₂) | T ₆ (B ₁ M ₂ S ₃ D ₂) | T ₇ (B ₁ M ₃ S ₁ D ₂) | T ₈ (B ₁ M ₃ S ₂ D ₂) | T ₉ (B ₁ M ₃ S ₃ D ₂) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 402.4 | 411.4 | 420.4 | 400.3 | 404.4 | 418.3 | 402.4 | 412.3 | 414.1 |
| 1 | 173.4 | 169.9 | 242.7 | 161.6 | 170.3 | 243.7 | 156.6 | 158.4 | 241.3 |
| 2 | 101.1 | 99.1 | 135.5 | 95.3 | 93.3 | 133.3 | 91.4 | 94.3 | 131.9 |
| 3 | 69.2 | 67.2 | 74.4 | 63.9 | 60.3 | 76.2 | 61.9 | 62.6 | 75.5 |
| 4 | 49.2 | 47.2 | 49.7 | 44.9 | 47.7 | 48.2 | 39.3 | 45.3 | 47.8 |
| 5 | 35.5 | 34.8 | 31.7 | 35.3 | 33.4 | 29.3 | 25.1 | 25.3 | 29.0 |
| 6 | 28.2 | 25.8 | 30.3 | 24.6 | 22.4 | 32.7 | 15.2 | 14.3 | 32.3 |
| 7 | 19.1 | 18.7 | 25.2 | 16.2 | 18.3 | 24.1 | 9.9 | 9.9 | 23.9 |
| 8 | 12.6 | 16.8 | 23.5 | 9.8 | 9.9 | 22.3 | | | 22.1 |
| 9 | 9.8 | 12.9 | 22.0 | | | 22.0 | | | 21.8 |
| 10 | | 10.0 | 21.6 | | | 21.7 | | | 21.5 |
| 11 | | | 20.5 | | | 20.5 | | | 20.3 |
| 12 | | | 18.9 | | | 19.0 | | | 18.8 |
| 13 | | | 18.5 | | | 18.4 | | | 18.2 |

| | | | | | | | | | |
|-----------|--|--|------|--|--|------|--|--|------|
| 14 | | | 18.0 | | | 17.8 | | | 17.7 |
| 15 | | | 17.4 | | | 17.2 | | | 17.0 |
| 16 | | | 17.7 | | | 17.5 | | | 17.3 |
| 17 | | | 16.3 | | | 16.1 | | | 16.0 |
| 18 | | | 16.0 | | | 15.9 | | | 15.7 |
| 19 | | | 15.3 | | | 15.1 | | | 15.0 |
| 20 | | | 14.8 | | | 14.6 | | | 14.5 |
| 21 | | | 14.4 | | | 14.2 | | | 14.1 |
| 22 | | | 13.9 | | | 13.7 | | | 13.6 |
| 23 | | | 13.6 | | | 13.5 | | | 13.3 |
| 24 | | | 13.0 | | | 12.9 | | | 12.8 |
| 25 | | | 13.0 | | | 12.8 | | | 12.7 |
| 26 | | | 13.0 | | | 12.8 | | | 12.7 |
| 27 | | | 13.0 | | | 12.8 | | | 12.7 |
| 28 | | | 12.9 | | | 12.7 | | | 12.6 |
| 29 | | | 12.8 | | | 12.6 | | | 12.5 |
| 30 | | | 12.6 | | | 12.4 | | | 12.3 |
| 31 | | | 12.4 | | | 12.3 | | | 12.1 |
| 32 | | | 12.1 | | | 12.0 | | | 11.8 |
| 33 | | | 11.9 | | | 11.8 | | | 11.7 |
| 34 | | | 11.4 | | | 11.3 | | | 11.2 |
| 35 | | | 11.0 | | | 10.9 | | | 10.8 |
| 36 | | | 10.7 | | | 10.6 | | | 10.5 |
| 37 | | | 10.1 | | | 10.0 | | | 9.9 |
| 38 | | | 10.1 | | | 10.0 | | | |
| 39 | | | 10.0 | | | 9.9 | | | |
| 40 | | | 10.0 | | | | | | |

APPENDIX – E2

Drying rate per given time interval of sun-dried turmeric at 70 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Drying rate per given time interval (g of water / 100 g of dry matter)/day | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Day | T₁ (B₁M₁S₁D₂) | T₂ (B₁M₁S₂D₂) | T₃ (B₁M₁S₃D₂) | T₄ (B₁M₂S₁D₂) | T₅ (B₁M₂S₂D₂) | T₆ (B₁M₂S₃D₂) | T₇ (B₁M₃S₁D₂) | T₈ (B₁M₃S₂D₂) | T₉ (B₁M₃S₃D₂) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 0.477 | 0.503 | 0.370 | 0.497 | 0.488 | 0.364 | 0.512 | 0.529 | 0.360 |
| 2 | 0.151 | 0.148 | 0.223 | 0.138 | 0.160 | 0.230 | 0.136 | 0.133 | 0.228 |
| 3 | 0.067 | 0.067 | 0.127 | 0.065 | 0.069 | 0.119 | 0.061 | 0.066 | 0.118 |
| 4 | 0.042 | 0.042 | 0.051 | 0.040 | 0.026 | 0.058 | 0.047 | 0.036 | 0.058 |
| 5 | 0.029 | 0.026 | 0.038 | 0.020 | 0.030 | 0.039 | 0.029 | 0.042 | 0.039 |
| 6 | 0.015 | 0.019 | 0.003 | 0.022 | 0.023 | -0.007 | 0.021 | 0.023 | -0.007 |
| 7 | 0.019 | 0.015 | 0.011 | 0.017 | 0.009 | 0.018 | 0.011 | 0.009 | 0.018 |
| 8 | 0.013 | 0.004 | 0.004 | 0.013 | 0.018 | 0.004 | | | 0.004 |
| 9 | 0.006 | 0.008 | 0.003 | | | 0.001 | | | 0.001 |
| 10 | | 0.006 | 0.001 | | | 0.001 | | | 0.001 |
| 11 | | | 0.002 | | | 0.003 | | | 0.003 |
| 12 | | | 0.003 | | | 0.003 | | | 0.003 |
| 13 | | | 0.001 | | | 0.001 | | | 0.001 |

| | | | | | | | | | |
|-----------|--|--|--------|--|--|--------|--|--|--------|
| 14 | | | 0.001 | | | 0.001 | | | 0.001 |
| 15 | | | 0.001 | | | 0.001 | | | 0.001 |
| 16 | | | -0.001 | | | -0.001 | | | -0.001 |
| 17 | | | 0.003 | | | 0.003 | | | 0.003 |
| 18 | | | 0.001 | | | 0.001 | | | 0.001 |
| 19 | | | 0.002 | | | 0.002 | | | 0.002 |
| 20 | | | 0.001 | | | 0.001 | | | 0.001 |
| 21 | | | 0.001 | | | 0.001 | | | 0.001 |
| 22 | | | 0.001 | | | 0.001 | | | 0.001 |
| 23 | | | 0.001 | | | 0.001 | | | 0.001 |
| 24 | | | 0.001 | | | 0.001 | | | 0.001 |
| 25 | | | 0.000 | | | 0.000 | | | 0.000 |
| 26 | | | 0.000 | | | 0.000 | | | 0.000 |
| 27 | | | 0.000 | | | 0.000 | | | 0.000 |
| 28 | | | 0.000 | | | 0.000 | | | 0.000 |
| 29 | | | 0.000 | | | 0.000 | | | 0.000 |
| 30 | | | 0.000 | | | 0.000 | | | 0.000 |
| 31 | | | 0.000 | | | 0.000 | | | 0.000 |
| 32 | | | 0.001 | | | 0.001 | | | 0.001 |
| 33 | | | 0.000 | | | 0.000 | | | 0.000 |
| 34 | | | 0.001 | | | 0.001 | | | 0.001 |
| 35 | | | 0.001 | | | 0.001 | | | 0.001 |
| 36 | | | 0.001 | | | 0.001 | | | 0.001 |
| 37 | | | 0.001 | | | 0.001 | | | 0.001 |
| 38 | | | 0.000 | | | 0.000 | | | |
| 39 | | | 0.000 | | | 0.000 | | | |
| 40 | | | 0.000 | | | | | | |

APPENDIX – E3

Moisture ratio of sun-dried turmeric at 70 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture ratio | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|---|
| Day | T₁ (B₁M₁S₁D₂) | T₂ (B₁M₁S₂D₂) | T₃ (B₁M₁S₃D₂) | T₄ (B₁M₂S₁D₂) | T₅ (B₁M₂S₂D₂) | T₆ (B₁M₂S₃D₂) | T₇ (B₁M₃S₁D₂) | T₈ (B₁M₃S₂D₂) | T₉ (B₁M₃S₃D₂) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1 | 0.417 | 0.398 | 0.567 | 0.389 | 0.407 | 0.573 | 0.374 | 0.369 | 0.572 |
| 2 | 0.233 | 0.222 | 0.306 | 0.219 | 0.211 | 0.302 | 0.208 | 0.210 | 0.302 |
| 3 | 0.151 | 0.143 | 0.157 | 0.138 | 0.128 | 0.162 | 0.133 | 0.131 | 0.162 |
| 4 | 0.100 | 0.093 | 0.097 | 0.090 | 0.096 | 0.094 | 0.075 | 0.088 | 0.094 |
| 5 | 0.065 | 0.062 | 0.053 | 0.065 | 0.060 | 0.048 | 0.039 | 0.038 | 0.047 |
| 6 | 0.047 | 0.039 | 0.050 | 0.038 | 0.032 | 0.056 | 0.014 | 0.011 | 0.055 |
| 7 | 0.024 | 0.022 | 0.037 | 0.016 | 0.021 | 0.035 | 0.000 | 0.000 | 0.035 |
| 8 | 0.007 | 0.017 | 0.033 | 0.000 | 0.000 | 0.030 | | | 0.030 |
| 9 | 0.000 | 0.007 | 0.029 | | | 0.030 | | | 0.029 |
| 10 | | 0.000 | 0.028 | | | 0.029 | | | 0.029 |
| 11 | | | 0.026 | | | 0.026 | | | 0.026 |
| 12 | | | 0.022 | | | 0.022 | | | 0.022 |
| 13 | | | 0.021 | | | 0.021 | | | 0.020 |

| | | | | | | | | | |
|-----------|--|--|-------|--|--|-------|--|--|-------|
| 14 | | | 0.020 | | | 0.020 | | | 0.019 |
| 15 | | | 0.018 | | | 0.018 | | | 0.018 |
| 16 | | | 0.019 | | | 0.019 | | | 0.018 |
| 17 | | | 0.015 | | | 0.015 | | | 0.015 |
| 18 | | | 0.015 | | | 0.015 | | | 0.014 |
| 19 | | | 0.013 | | | 0.013 | | | 0.012 |
| 20 | | | 0.012 | | | 0.012 | | | 0.011 |
| 21 | | | 0.011 | | | 0.011 | | | 0.010 |
| 22 | | | 0.009 | | | 0.009 | | | 0.009 |
| 23 | | | 0.009 | | | 0.009 | | | 0.008 |
| 24 | | | 0.007 | | | 0.007 | | | 0.007 |
| 25 | | | 0.007 | | | 0.007 | | | 0.007 |
| 26 | | | 0.007 | | | 0.007 | | | 0.007 |
| 27 | | | 0.007 | | | 0.007 | | | 0.007 |
| 28 | | | 0.007 | | | 0.007 | | | 0.007 |
| 29 | | | 0.007 | | | 0.007 | | | 0.006 |
| 30 | | | 0.006 | | | 0.006 | | | 0.006 |
| 31 | | | 0.006 | | | 0.006 | | | 0.006 |
| 32 | | | 0.005 | | | 0.005 | | | 0.005 |
| 33 | | | 0.005 | | | 0.005 | | | 0.004 |
| 34 | | | 0.003 | | | 0.003 | | | 0.003 |
| 35 | | | 0.003 | | | 0.002 | | | 0.002 |
| 36 | | | 0.002 | | | 0.002 | | | 0.001 |
| 37 | | | 0.000 | | | 0.000 | | | 0.000 |
| 38 | | | 0.000 | | | 0.000 | | | |
| 39 | | | 0.000 | | | 0.000 | | | |
| 40 | | | 0.000 | | | | | | |

APPENDIX – F1

Moisture content of sun-dried turmeric at 80 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture content (% d. b.) | | | | | | | | | |
|----------------------------|---|---|---|---|---|---|---|---|---|
| Day | T ₁₀ (B ₂ M ₁ S ₁ D ₂) | T ₁₁ (B ₂ M ₁ S ₂ D ₂) | T ₁₂ (B ₂ M ₁ S ₃ D ₂) | T ₁₃ (B ₂ M ₂ S ₁ D ₂) | T ₁₄ (B ₂ M ₂ S ₂ D ₂) | T ₁₅ (B ₂ M ₂ S ₃ D ₂) | T ₁₆ (B ₂ M ₃ S ₁ D ₂) | T ₁₇ (B ₂ M ₃ S ₂ D ₂) | T ₁₈ (B ₂ M ₃ S ₃ D ₂) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 403.1544 | 401.3625 | 409.94 | 400.5685 | 401.2399 | 403.27 | 401.3325 | 400.362 | 402.97 |
| 1 | 171.6397 | 172.3625 | 238.85 | 151.2658 | 161.3985 | 266.53 | 157.3268 | 161.2655 | 263.87 |
| 2 | 100.115 | 100.115 | 130.61 | 95.2358 | 95.1659 | 162.58 | 125.3265 | 101.3266 | 160.96 |
| 3 | 68.46385 | 67.86331 | 74.70 | 58.1258 | 69.1558 | 99.19 | 63.2155 | 60.3325 | 98.20 |
| 4 | 48.66385 | 47.64494 | 47.28 | 43.04175 | 40.1658 | 75.94 | 45.1255 | 39.968 | 75.19 |
| 5 | 35.11000 | 35.1698 | 28.74 | 31.71786 | 28.1255 | 57.74 | 35.1552 | 28.3265 | 57.17 |
| 6 | 27.88385 | 26.6598 | 32.01 | 19.2315 | 16.2659 | 47.38 | 18.2658 | 16.2355 | 46.91 |
| 7 | 18.91329 | 17.6958 | 23.65 | 9.9658 | 9.8654 | 42.59 | 9.7548 | 9.8565 | 42.16 |
| 8 | 12.50024 | 11.9654 | 21.88 | | | 38.29 | | | 37.91 |
| 9 | 9.659331 | 9.8565 | 21.60 | | | 36.91 | | | 36.55 |
| 10 | | | 21.28 | | | 35.00 | | | 34.65 |
| 11 | | | 20.06 | | | 30.31 | | | 30.01 |
| 12 | | | 18.63 | | | 28.90 | | | 28.61 |
| 13 | | | 17.99 | | | 27.78 | | | 27.50 |
| 14 | | | 17.49 | | | 24.32 | | | 24.07 |
| 15 | | | 16.85 | | | 24.21 | | | 23.97 |

| | | | | | | | | | |
|-----------|--|--|-------|--|--|-------|--|--|-------|
| 16 | | | 17.17 | | | 21.13 | | | 20.92 |
| 17 | | | 15.81 | | | 17.86 | | | 17.68 |
| 18 | | | 15.55 | | | 16.40 | | | 16.23 |
| 19 | | | 14.82 | | | 15.92 | | | 15.76 |
| 20 | | | 14.36 | | | 15.50 | | | 15.34 |
| 21 | | | 13.94 | | | 14.27 | | | 14.12 |
| 22 | | | 13.45 | | | 13.12 | | | 12.98 |
| 23 | | | 13.19 | | | 12.89 | | | 12.76 |
| 24 | | | 12.62 | | | 12.51 | | | 12.39 |
| 25 | | | 12.57 | | | 12.22 | | | 12.10 |
| 26 | | | 12.57 | | | 11.91 | | | 11.79 |
| 27 | | | 12.57 | | | 11.57 | | | 11.46 |
| 28 | | | 12.49 | | | 11.40 | | | 11.28 |
| 29 | | | 12.38 | | | 10.99 | | | 10.88 |
| 30 | | | 12.18 | | | 10.86 | | | 10.75 |
| 31 | | | 12.03 | | | 10.75 | | | 10.64 |
| 32 | | | 11.73 | | | 10.55 | | | 10.45 |
| 33 | | | 11.54 | | | 10.36 | | | 10.26 |
| 34 | | | 11.06 | | | 10.12 | | | 10.02 |
| 35 | | | 10.89 | | | 10.06 | | | 9.96 |
| 36 | | | 10.38 | | | 9.99 | | | |
| 37 | | | 10.03 | | | 9.90 | | | |
| 38 | | | 9.97 | | | | | | |
| 39 | | | 9.71 | | | | | | |

APPENDIX – F2

Drying rate per given time interval of sun-dried turmeric at 80 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Drying rate per given time interval (g of water / 100 g of dry matter)/day | | | | | | | | | |
|---|--|--|--|--|--|--|--|--|--|
| Day | T₁₀ (B₂M₁S₁D₂) | T₁₁ (B₂M₁S₂D₂) | T₁₂ (B₂M₁S₃D₂) | T₁₃ (B₂M₂S₁D₂) | T₁₄ (B₂M₂S₂D₂) | T₁₅ (B₂M₂S₃D₂) | T₁₆ (B₂M₃S₁D₂) | T₁₇ (B₂M₃S₂D₂) | T₁₈ (B₂M₃S₃D₂) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0.482 | 0.477 | 0.356 | 0.519 | 0.500 | 0.285 | 0.508 | 0.498 | 0.290 |
| 2 | 0.149 | 0.151 | 0.225 | 0.117 | 0.138 | 0.217 | 0.067 | 0.125 | 0.214 |
| 3 | 0.066 | 0.067 | 0.116 | 0.077 | 0.054 | 0.132 | 0.129 | 0.085 | 0.131 |
| 4 | 0.041 | 0.042 | 0.057 | 0.031 | 0.060 | 0.048 | 0.038 | 0.042 | 0.048 |
| 5 | 0.028 | 0.026 | 0.039 | 0.024 | 0.025 | 0.038 | 0.021 | 0.024 | 0.038 |
| 6 | 0.015 | 0.018 | -0.007 | 0.026 | 0.025 | 0.022 | 0.035 | 0.025 | 0.021 |
| 7 | 0.019 | 0.019 | 0.017 | 0.019 | 0.013 | 0.010 | 0.018 | 0.013 | 0.010 |
| 8 | 0.013 | 0.012 | 0.004 | | | 0.009 | | | 0.009 |
| 9 | 0.006 | 0.004 | 0.001 | | | 0.003 | | | 0.003 |
| 10 | | | 0.001 | | | 0.004 | | | 0.004 |
| 11 | | | 0.003 | | | 0.010 | | | 0.010 |
| 12 | | | 0.003 | | | 0.003 | | | 0.003 |
| 13 | | | 0.001 | | | 0.002 | | | 0.002 |
| 14 | | | 0.001 | | | 0.007 | | | 0.007 |
| 15 | | | 0.001 | | | 0.000 | | | 0.000 |
| 16 | | | -0.001 | | | 0.006 | | | 0.006 |
| 17 | | | 0.003 | | | 0.007 | | | 0.007 |

| | | | | | | | | | |
|-----------|--|--|-------|--|--|-------|--|--|-------|
| 18 | | | 0.001 | | | 0.003 | | | 0.003 |
| 19 | | | 0.002 | | | 0.001 | | | 0.001 |
| 20 | | | 0.001 | | | 0.001 | | | 0.001 |
| 21 | | | 0.001 | | | 0.003 | | | 0.003 |
| 22 | | | 0.001 | | | 0.002 | | | 0.002 |
| 23 | | | 0.001 | | | 0.000 | | | 0.000 |
| 24 | | | 0.001 | | | 0.001 | | | 0.001 |
| 25 | | | 0.000 | | | 0.001 | | | 0.001 |
| 26 | | | 0.000 | | | 0.001 | | | 0.001 |
| 27 | | | 0.000 | | | 0.001 | | | 0.001 |
| 28 | | | 0.000 | | | 0.000 | | | 0.000 |
| 29 | | | 0.000 | | | 0.001 | | | 0.001 |
| 30 | | | 0.000 | | | 0.000 | | | 0.000 |
| 31 | | | 0.000 | | | 0.000 | | | 0.000 |
| 32 | | | 0.001 | | | 0.000 | | | 0.000 |
| 33 | | | 0.000 | | | 0.000 | | | 0.000 |
| 34 | | | 0.001 | | | 0.001 | | | 0.000 |
| 35 | | | 0.000 | | | 0.000 | | | 0.000 |
| 36 | | | 0.001 | | | 0.000 | | | |
| 37 | | | 0.001 | | | 0.000 | | | |
| 38 | | | 0.000 | | | | | | |
| 39 | | | 0.001 | | | | | | |

APPENDIX – F3

Moisture ratio of sun-dried turmeric at 80 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture ratio | | | | | | | | | |
|-----------------------|--|--|--|--|--|--|--|--|--|
| Day | T₁₀ (B₂M₁S₁D₂) | T₁₁ (B₂M₁S₂D₂) | T₁₂ (B₂M₁S₃D₂) | T₁₃ (B₂M₂S₁D₂) | T₁₄ (B₂M₂S₂D₂) | T₁₅ (B₂M₂S₃D₂) | T₁₆ (B₂M₃S₁D₂) | T₁₇ (B₂M₃S₂D₂) | T₁₈ (B₂M₃S₃D₂) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0.412 | 0.415 | 0.573 | 0.362 | 0.387 | 0.652 | 0.377 | 0.388 | 0.646 |
| 2 | 0.230 | 0.231 | 0.302 | 0.218 | 0.218 | 0.388 | 0.295 | 0.234 | 0.384 |
| 3 | 0.149 | 0.148 | 0.162 | 0.123 | 0.151 | 0.227 | 0.137 | 0.129 | 0.225 |
| 4 | 0.099 | 0.097 | 0.094 | 0.085 | 0.077 | 0.168 | 0.090 | 0.077 | 0.166 |
| 5 | 0.065 | 0.065 | 0.048 | 0.056 | 0.047 | 0.122 | 0.065 | 0.047 | 0.120 |
| 6 | 0.046 | 0.043 | 0.056 | 0.024 | 0.016 | 0.095 | 0.022 | 0.016 | 0.094 |
| 7 | 0.024 | 0.020 | 0.035 | 0.000 | 0.000 | 0.083 | 0.000 | 0.000 | 0.082 |
| 8 | 0.007 | 0.005 | 0.030 | | | 0.072 | | | 0.071 |
| 9 | 0.000 | 0.000 | 0.030 | | | 0.069 | | | 0.068 |
| 10 | | | 0.029 | | | 0.064 | | | 0.063 |
| 11 | | | 0.026 | | | 0.052 | | | 0.051 |
| 12 | | | 0.022 | | | 0.048 | | | 0.047 |
| 13 | | | 0.021 | | | 0.045 | | | 0.045 |
| 14 | | | 0.019 | | | 0.037 | | | 0.036 |
| 15 | | | 0.018 | | | 0.036 | | | 0.036 |

| | | | | | | | | | |
|-----------|--|--|-------|--|--|-------|--|--|-------|
| 16 | | | 0.019 | | | 0.029 | | | 0.028 |
| 17 | | | 0.015 | | | 0.020 | | | 0.020 |
| 18 | | | 0.015 | | | 0.017 | | | 0.016 |
| 19 | | | 0.013 | | | 0.015 | | | 0.015 |
| 20 | | | 0.012 | | | 0.014 | | | 0.014 |
| 21 | | | 0.011 | | | 0.011 | | | 0.011 |
| 22 | | | 0.009 | | | 0.008 | | | 0.008 |
| 23 | | | 0.009 | | | 0.008 | | | 0.007 |
| 24 | | | 0.007 | | | 0.007 | | | 0.006 |
| 25 | | | 0.007 | | | 0.006 | | | 0.005 |
| 26 | | | 0.007 | | | 0.005 | | | 0.005 |
| 27 | | | 0.007 | | | 0.004 | | | 0.004 |
| 28 | | | 0.007 | | | 0.004 | | | 0.003 |
| 29 | | | 0.007 | | | 0.003 | | | 0.002 |
| 30 | | | 0.006 | | | 0.002 | | | 0.002 |
| 31 | | | 0.006 | | | 0.002 | | | 0.002 |
| 32 | | | 0.005 | | | 0.002 | | | 0.001 |
| 33 | | | 0.005 | | | 0.001 | | | 0.001 |
| 34 | | | 0.003 | | | 0.001 | | | 0.000 |
| 35 | | | 0.003 | | | 0.000 | | | 0.000 |
| 36 | | | 0.002 | | | 0.000 | | | |
| 37 | | | 0.001 | | | 0.000 | | | |
| 38 | | | 0.001 | | | | | | |
| 39 | | | 0.000 | | | | | | |

APPENDIX – G1

Moisture content of sun-dried turmeric at 90 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture content (% d. b.) | | | | | | | | | |
|----------------------------|---|---|---|---|---|---|---|---|---|
| Day | T ₁₉ (B ₃ M ₁ S ₁ D ₂) | T ₂₀ (B ₃ M ₁ S ₂ D ₂) | T ₂₁ (B ₃ M ₁ S ₃ D ₂) | T ₂₂ (B ₃ M ₂ S ₁ D ₂) | T ₂₃ (B ₃ M ₂ S ₂ D ₂) | T ₂₄ (B ₃ M ₂ S ₃ D ₂) | T ₂₅ (B ₃ M ₃ S ₁ D ₂) | T ₂₆ (B ₃ M ₃ S ₂ D ₂) | T ₂₇ (B ₃ M ₃ S ₃ D ₂) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 405.3 | 405.0 | 402.4 | 402.4 | 404.3 | 401.0 | 401.3 | 405.3 | 400.0 |
| 1 | 155.2 | 166.5 | 261.2 | 150.4 | 145.3 | 258.6 | 151.4 | 157.7 | 256.0 |
| 2 | 93.3 | 97.1 | 159.3 | 90.3 | 88.6 | 157.8 | 117.3 | 125.3 | 156.2 |
| 3 | 60.2 | 65.8 | 97.2 | 57.3 | 63.3 | 96.2 | 70.3 | 42.3 | 95.3 |
| 4 | 40.3 | 44.3 | 74.4 | 45.3 | 39.3 | 73.7 | 31.7 | 27.2 | 73.0 |
| 5 | 30.2 | 36.1 | 56.6 | 24.3 | 27.3 | 56.0 | 17.3 | 15.3 | 55.5 |
| 6 | 21.3 | 24.1 | 46.4 | 14.3 | 16.3 | 46.0 | 10.0 | 10.0 | 45.5 |
| 7 | 14.4 | 15.3 | 41.7 | 9.9 | 9.5 | 41.3 | | | 40.9 |
| 8 | 9.7 | 9.8 | 37.5 | | | 37.2 | | | 36.8 |
| 9 | | | 36.2 | | | 35.8 | | | 35.5 |
| 10 | | | 34.3 | | | 34.0 | | | 33.6 |
| 11 | | | 29.7 | | | 29.4 | | | 29.1 |
| 12 | | | 28.3 | | | 28.0 | | | 27.8 |
| 13 | | | 27.2 | | | 27.0 | | | 26.7 |
| 14 | | | 23.8 | | | 23.6 | | | 23.4 |
| 15 | | | 23.7 | | | 23.5 | | | 23.3 |

| | | | | | | | | | |
|-----------|--|--|------|--|--|------|--|--|------|
| 16 | | | 20.7 | | | 20.5 | | | 20.3 |
| 17 | | | 17.5 | | | 17.3 | | | 17.2 |
| 18 | | | 16.1 | | | 15.9 | | | 15.8 |
| 19 | | | 15.6 | | | 15.4 | | | 15.3 |
| 20 | | | 15.2 | | | 15.0 | | | 14.9 |
| 21 | | | 14.0 | | | 13.8 | | | 13.7 |
| 22 | | | 12.9 | | | 12.7 | | | 12.6 |
| 23 | | | 12.6 | | | 12.5 | | | 12.4 |
| 24 | | | 12.3 | | | 12.1 | | | 12.0 |
| 25 | | | 12.0 | | | 11.9 | | | 11.7 |
| 26 | | | 11.7 | | | 11.6 | | | 11.4 |
| 27 | | | 11.3 | | | 11.2 | | | 11.1 |
| 28 | | | 11.2 | | | 11.1 | | | 10.9 |
| 29 | | | 10.8 | | | 10.7 | | | 10.6 |
| 30 | | | 10.6 | | | 10.5 | | | 10.4 |
| 31 | | | 10.5 | | | 10.4 | | | 10.3 |
| 32 | | | 10.3 | | | 10.2 | | | 10.1 |
| 33 | | | 10.3 | | | 10.2 | | | 10.1 |
| 34 | | | 10.1 | | | 10.0 | | | 9.9 |
| 35 | | | 10.0 | | | 9.9 | | | |
| 36 | | | 10.0 | | | 9.9 | | | |
| 37 | | | 10.0 | | | | | | |
| 38 | | | 9.6 | | | | | | |

APPENDIX – G2

Drying rate per given time interval of sun-dried turmeric at 90 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Drying rate per given time interval (g of water / 100 g of dry matter)/day | | | | | | | | | |
|---|--|--|--|--|--|--|--|--|--|
| Day | T₁₉ (B₃M₁S₁D₂) | T₂₀ (B₃M₁S₂D₂) | T₂₁ (B₃M₁S₃D₂) | T₂₂ (B₃M₂S₁D₂) | T₂₃ (B₃M₂S₂D₂) | T₂₄ (B₃M₂S₃D₂) | T₂₅ (B₃M₃S₁D₂) | T₂₆ (B₃M₃S₂D₂) | T₂₇ (B₃M₃S₃D₂) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0.521 | 0.497 | 0.278 | 0.525 | 0.539 | 0.297 | 0.521 | 0.516 | 0.300 |
| 2 | 0.129 | 0.145 | 0.228 | 0.125 | 0.118 | 0.210 | 0.071 | 0.067 | 0.208 |
| 3 | 0.069 | 0.065 | 0.129 | 0.069 | 0.053 | 0.128 | 0.098 | 0.173 | 0.127 |
| 4 | 0.042 | 0.045 | 0.047 | 0.025 | 0.050 | 0.047 | 0.080 | 0.031 | 0.047 |
| 5 | 0.021 | 0.017 | 0.037 | 0.044 | 0.025 | 0.037 | 0.030 | 0.025 | 0.036 |
| 6 | 0.018 | 0.025 | 0.021 | 0.021 | 0.023 | 0.021 | 0.015 | 0.011 | 0.021 |
| 7 | 0.014 | 0.018 | 0.010 | 0.009 | 0.014 | 0.010 | | | 0.010 |
| 8 | 0.010 | 0.011 | 0.009 | | | 0.009 | | | 0.009 |
| 9 | | | 0.003 | | | 0.003 | | | 0.003 |
| 10 | | | 0.004 | | | 0.004 | | | 0.004 |
| 11 | | | 0.010 | | | 0.009 | | | 0.009 |
| 12 | | | 0.003 | | | 0.003 | | | 0.003 |
| 13 | | | 0.002 | | | 0.002 | | | 0.002 |

| | | | | | | | | | |
|-----------|--|--|-------|--|--|-------|--|--|-------|
| 14 | | | 0.007 | | | 0.007 | | | 0.007 |
| 15 | | | 0.000 | | | 0.000 | | | 0.000 |
| 16 | | | 0.006 | | | 0.006 | | | 0.006 |
| 17 | | | 0.007 | | | 0.007 | | | 0.007 |
| 18 | | | 0.003 | | | 0.003 | | | 0.003 |
| 19 | | | 0.001 | | | 0.001 | | | 0.001 |
| 20 | | | 0.001 | | | 0.001 | | | 0.001 |
| 21 | | | 0.003 | | | 0.002 | | | 0.002 |
| 22 | | | 0.002 | | | 0.002 | | | 0.002 |
| 23 | | | 0.000 | | | 0.000 | | | 0.000 |
| 24 | | | 0.001 | | | 0.001 | | | 0.001 |
| 25 | | | 0.001 | | | 0.001 | | | 0.001 |
| 26 | | | 0.001 | | | 0.001 | | | 0.001 |
| 27 | | | 0.001 | | | 0.001 | | | 0.001 |
| 28 | | | 0.000 | | | 0.000 | | | 0.000 |
| 29 | | | 0.001 | | | 0.001 | | | 0.001 |
| 30 | | | 0.000 | | | 0.000 | | | 0.000 |
| 31 | | | 0.000 | | | 0.000 | | | 0.000 |
| 32 | | | 0.000 | | | 0.000 | | | 0.000 |
| 33 | | | 0.000 | | | 0.000 | | | 0.000 |
| 34 | | | 0.000 | | | 0.000 | | | 0.000 |
| 35 | | | 0.000 | | | 0.000 | | | |
| 36 | | | 0.000 | | | 0.000 | | | |
| 37 | | | 0.000 | | | | | | |
| 38 | | | 0.00 | | | | | | |

APPENDIX – G3

Moisture ratio of sun-dried turmeric at 90 °C blanching temperatures with varying blanching times and different slices (4 mm, 5 mm and whole) of turmeric

| Moisture ratio | | | | | | | | | |
|-----------------------|--|--|--|--|--|--|--|--|--|
| Day | T₁₉ (B₃M₁S₁D₂) | T₂₀ (B₃M₁S₂D₂) | T₂₁ (B₃M₁S₃D₂) | T₂₂ (B₃M₂S₁D₂) | T₂₃ (B₃M₂S₂D₂) | T₂₄ (B₃M₂S₃D₂) | T₂₅ (B₃M₃S₁D₂) | T₂₆ (B₃M₃S₂D₂) | T₂₇ (B₃M₃S₃D₂) |
| | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole | 4 mm | 5 mm | whole |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0.368 | 0.397 | 0.660 | 0.358 | 0.344 | 0.636 | 0.361 | 0.374 | 0.631 |
| 2 | 0.211 | 0.221 | 0.381 | 0.205 | 0.201 | 0.378 | 0.274 | 0.292 | 0.375 |
| 3 | 0.128 | 0.142 | 0.223 | 0.121 | 0.136 | 0.221 | 0.154 | 0.082 | 0.219 |
| 4 | 0.077 | 0.087 | 0.165 | 0.090 | 0.076 | 0.163 | 0.055 | 0.044 | 0.162 |
| 5 | 0.052 | 0.067 | 0.120 | 0.037 | 0.045 | 0.118 | 0.019 | 0.013 | 0.117 |
| 6 | 0.029 | 0.036 | 0.094 | 0.011 | 0.017 | 0.092 | 0.000 | 0.000 | 0.091 |
| 7 | 0.012 | 0.014 | 0.082 | 0.000 | 0.000 | 0.080 | | | 0.079 |
| 8 | 0.000 | 0.000 | 0.071 | | | 0.070 | | | 0.069 |
| 9 | | | 0.068 | | | 0.066 | | | 0.066 |
| 10 | | | 0.063 | | | 0.062 | | | 0.061 |
| 11 | | | 0.051 | | | 0.050 | | | 0.049 |
| 12 | | | 0.048 | | | 0.046 | | | 0.046 |
| 13 | | | 0.045 | | | 0.044 | | | 0.043 |
| 14 | | | 0.036 | | | 0.035 | | | 0.035 |

| | | | | | | | | | |
|-----------|--|--|-------|--|--|-------|--|--|-------|
| 15 | | | 0.036 | | | 0.035 | | | 0.034 |
| 16 | | | 0.028 | | | 0.027 | | | 0.027 |
| 17 | | | 0.020 | | | 0.019 | | | 0.019 |
| 18 | | | 0.016 | | | 0.015 | | | 0.015 |
| 19 | | | 0.015 | | | 0.014 | | | 0.014 |
| 20 | | | 0.014 | | | 0.013 | | | 0.013 |
| 21 | | | 0.011 | | | 0.010 | | | 0.010 |
| 22 | | | 0.008 | | | 0.007 | | | 0.007 |
| 23 | | | 0.008 | | | 0.007 | | | 0.006 |
| 24 | | | 0.007 | | | 0.006 | | | 0.005 |
| 25 | | | 0.006 | | | 0.005 | | | 0.005 |
| 26 | | | 0.005 | | | 0.004 | | | 0.004 |
| 27 | | | 0.004 | | | 0.003 | | | 0.003 |
| 28 | | | 0.004 | | | 0.003 | | | 0.003 |
| 29 | | | 0.003 | | | 0.002 | | | 0.002 |
| 30 | | | 0.003 | | | 0.002 | | | 0.001 |
| 31 | | | 0.002 | | | 0.001 | | | 0.001 |
| 32 | | | 0.002 | | | 0.001 | | | 0.001 |
| 33 | | | 0.002 | | | 0.001 | | | 0.000 |
| 34 | | | 0.001 | | | 0.000 | | | |
| 35 | | | 0.001 | | | 0.000 | | | |
| 36 | | | 0.001 | | | | | | |
| 37 | | | 0.001 | | | | | | |

APPENDIX – H1

Experimental values of different biochemical properties of various blanching temperatures, times and slices (4 mm, 5 mm and whole) of turmeric dried by solar tunnel dryer

| Sr. no. | Treatments | M. C. (w.b.) % | Total Carbohydrate (%) | True Protein (%) | Total Oil (%) | Total Ash (%) | Total Phenol (%) | Antioxidant activity (%) | Curcumin content (%) | Volatile oil (%) |
|---------|--|----------------|------------------------|------------------|---------------|---------------|------------------|--------------------------|----------------------|------------------|
| 1 | T ₁ (B ₁ M ₁ S ₁ D ₁) | 9.81 | 59.03 | 9.51 | 4.61 | 7.42 | 2.97 | 44.86 | 4.00 | 3.76 |
| 2 | T ₂ (B ₁ M ₁ S ₂ D ₁) | 9.77 | 60.24 | 10.01 | 4.70 | 8.09 | 2.88 | 46.25 | 4.08 | 3.84 |
| 3 | T ₃ (B ₁ M ₁ S ₃ D ₁) | 9.73 | 63.41 | 9.07 | 4.90 | 8.57 | 2.77 | 42.09 | 4.18 | 4.00 |
| 4 | T ₄ (B ₁ M ₂ S ₁ D ₁) | 9.85 | 53.30 | 8.63 | 4.27 | 6.98 | 2.89 | 41.93 | 3.26 | 3.49 |
| 5 | T ₅ (B ₁ M ₂ S ₂ D ₁) | 9.84 | 54.39 | 9.08 | 4.36 | 7.24 | 2.80 | 43.23 | 3.36 | 3.60 |
| 6 | T ₆ (B ₁ M ₂ S ₃ D ₁) | 9.81 | 57.25 | 8.57 | 4.54 | 8.21 | 2.61 | 39.34 | 4.09 | 3.80 |
| 7 | T ₇ (B ₁ M ₃ S ₁ D ₁) | 9.90 | 48.51 | 7.93 | 3.48 | 6.56 | 2.77 | 38.97 | 2.90 | 3.29 |
| 8 | T ₈ (B ₁ M ₃ S ₂ D ₁) | 9.90 | 49.50 | 8.30 | 3.55 | 6.85 | 2.69 | 40.18 | 3.01 | 3.39 |
| 9 | T ₉ (B ₁ M ₃ S ₃ D ₁) | 9.84 | 52.11 | 7.89 | 3.70 | 7.58 | 2.36 | 36.56 | 3.62 | 3.40 |
| 10 | T ₁₀ (B ₂ M ₁ S ₁ D ₁) | 9.85 | 54.55 | 9.47 | 4.52 | 7.07 | 2.95 | 44.05 | 3.58 | 3.72 |
| 11 | T ₁₁ (B ₂ M ₁ S ₂ D ₁) | 9.85 | 55.66 | 9.96 | 4.61 | 7.77 | 2.86 | 45.41 | 3.65 | 3.80 |
| 12 | T ₁₂ (B ₂ M ₁ S ₃ D ₁) | 9.77 | 58.59 | 8.72 | 4.80 | 8.49 | 2.66 | 41.32 | 4.15 | 3.92 |
| 13 | T ₁₃ (B ₂ M ₂ S ₁ D ₁) | 9.88 | 49.74 | 8.48 | 4.10 | 6.87 | 2.85 | 41.50 | 3.26 | 3.30 |
| 14 | T ₁₄ (B ₂ M ₂ S ₂ D ₁) | 9.91 | 50.75 | 8.92 | 4.18 | 7.11 | 2.76 | 42.78 | 3.36 | 3.40 |
| 15 | T ₁₅ (B ₂ M ₂ S ₃ D ₁) | 9.80 | 53.42 | 8.39 | 4.36 | 7.91 | 2.59 | 38.93 | 4.01 | 3.75 |
| 16 | T ₁₆ (B ₂ M ₃ S ₁ D ₁) | 9.95 | 45.75 | 7.81 | 3.35 | 6.52 | 2.41 | 36.88 | 2.85 | 3.10 |

| | | | | | | | | | | |
|-----------|---|------|-------|------|------|------|------|-------|------|------|
| 17 | T₁₇(B₂M₃S₂D₁) | 9.93 | 46.69 | 8.13 | 3.42 | 6.79 | 2.34 | 38.02 | 2.95 | 3.20 |
| 18 | T₁₈(B₂M₃S₃D₁) | 9.86 | 49.14 | 7.72 | 3.56 | 6.66 | 2.29 | 34.60 | 2.69 | 3.40 |
| 19 | T₁₉(B₃M₁S₁D₁) | 9.93 | 50.63 | 9.33 | 4.42 | 7.01 | 2.91 | 43.70 | 3.32 | 3.53 |
| 20 | T₂₀(B₃M₁S₂D₁) | 9.87 | 51.67 | 9.82 | 4.51 | 7.31 | 2.82 | 45.05 | 3.39 | 3.60 |
| 21 | T₂₁(B₃M₁S₃D₁) | 9.80 | 54.39 | 8.62 | 4.69 | 8.37 | 2.63 | 41.00 | 4.11 | 3.80 |
| 22 | T₂₂(B₃M₂S₁D₁) | 9.96 | 45.47 | 8.25 | 3.64 | 6.72 | 2.82 | 40.34 | 3.02 | 3.30 |
| 23 | T₂₃(B₃M₂S₂D₁) | 9.92 | 46.40 | 8.68 | 3.72 | 6.93 | 2.73 | 41.59 | 3.11 | 3.40 |
| 24 | T₂₄(B₃M₂S₃D₁) | 9.90 | 48.84 | 8.16 | 3.87 | 7.85 | 2.48 | 37.85 | 3.85 | 3.59 |
| 25 | T₂₅(B₃M₃S₁D₁) | 9.97 | 42.89 | 7.73 | 3.01 | 6.36 | 2.21 | 33.85 | 2.17 | 2.91 |
| 26 | T₂₆(B₃M₃S₂D₁) | 9.97 | 43.77 | 7.98 | 3.07 | 6.40 | 2.14 | 34.90 | 2.25 | 3.00 |
| 27 | T₂₇(B₃M₃S₃D₁) | 9.96 | 46.07 | 7.58 | 3.20 | 6.46 | 2.04 | 31.76 | 2.37 | 3.39 |

APPENDIX – H2

Experimental values of different biochemical properties of various blanching temperatures, times and slices (4 mm, 5 mm and whole) of turmeric dried by sun drying

| Sr. no. | Treatments | M. C. (w.b.) % | Total Carbohydrate (%) | True Protein (%) | Total Oil (%) | Total Ash (%) | Total Phenol (%) | Antioxidant activity (%) | Curcumin content (%) | Volatile oil (%) |
|----------------|---|-----------------------|-------------------------------|-------------------------|----------------------|----------------------|-------------------------|---------------------------------|-----------------------------|-------------------------|
| 1 | T₁(B₁M₁S₁D₂) | 9.84 | 52.30 | 8.66 | 4.01 | 6.75 | 2.89 | 42.59 | 3.70 | 3.33 |
| 2 | T₂(B₁M₁S₂D₂) | 9.81 | 53.10 | 9.12 | 4.10 | 7.36 | 2.80 | 43.91 | 3.77 | 3.40 |
| 3 | T₃(B₁M₁S₃D₂) | 9.77 | 55.31 | 8.23 | 4.27 | 7.80 | 2.44 | 39.96 | 3.91 | 3.55 |
| 4 | T₄(B₁M₂S₁D₂) | 9.89 | 50.87 | 7.86 | 3.71 | 6.35 | 2.66 | 39.45 | 2.99 | 3.15 |
| 5 | T₅(B₁M₂S₂D₂) | 9.88 | 51.64 | 8.28 | 3.79 | 6.59 | 2.58 | 40.67 | 3.08 | 3.25 |
| 6 | T₆(B₁M₂S₃D₂) | 9.84 | 53.80 | 7.47 | 3.95 | 7.47 | 2.32 | 37.01 | 3.78 | 3.25 |
| 7 | T₇(B₁M₃S₁D₂) | 9.95 | 45.36 | 7.18 | 3.02 | 5.97 | 2.46 | 34.72 | 2.72 | 2.95 |
| 8 | T₈(B₁M₃S₂D₂) | 9.91 | 46.05 | 7.56 | 3.09 | 6.23 | 2.38 | 35.79 | 2.82 | 3.04 |
| 9 | T₉(B₁M₃S₃D₂) | 9.87 | 47.97 | 6.82 | 3.22 | 6.90 | 2.08 | 32.57 | 3.26 | 3.00 |
| 10 | T₁₀(B₂M₁S₁D₂) | 9.85 | 51.25 | 8.62 | 3.95 | 6.43 | 2.83 | 41.09 | 3.25 | 3.28 |
| 11 | T₁₁(B₂M₁S₂D₂) | 9.87 | 52.03 | 9.07 | 4.03 | 7.07 | 2.75 | 42.36 | 3.32 | 3.35 |
| 12 | T₁₂(B₂M₁S₃D₂) | 9.82 | 54.20 | 8.19 | 4.20 | 7.73 | 2.34 | 38.55 | 3.89 | 3.55 |
| 13 | T₁₃(B₂M₂S₁D₂) | 9.90 | 46.45 | 7.71 | 3.56 | 6.25 | 2.56 | 38.29 | 2.95 | 2.96 |
| 14 | T₁₄(B₂M₂S₂D₂) | 9.91 | 47.15 | 8.11 | 3.63 | 6.47 | 2.48 | 39.47 | 3.04 | 3.15 |

| | | | | | | | | | | |
|-----------|---|------|-------|------|------|------|------|-------|------|------|
| 15 | T₁₅(B₂M₂S₃D₂) | 9.89 | 49.12 | 7.32 | 3.78 | 7.20 | 2.28 | 35.92 | 3.65 | 3.22 |
| 16 | T₁₆(B₂M₃S₁D₂) | 9.96 | 42.75 | 7.01 | 2.91 | 5.93 | 2.12 | 32.10 | 2.59 | 2.87 |
| 17 | T₁₇(B₂M₃S₂D₂) | 9.94 | 43.41 | 7.37 | 2.97 | 6.18 | 2.06 | 33.09 | 2.69 | 2.96 |
| 18 | T₁₈(B₂M₃S₃D₂) | 9.94 | 45.21 | 6.66 | 3.10 | 6.06 | 2.02 | 30.11 | 2.47 | 3.10 |
| 19 | T₁₉(B₃M₁S₁D₂) | 9.91 | 47.34 | 8.49 | 3.84 | 6.38 | 2.73 | 39.97 | 3.11 | 3.18 |
| 20 | T₂₀(B₃M₁S₂D₂) | 9.9 | 48.06 | 8.94 | 3.92 | 6.65 | 2.65 | 41.21 | 3.17 | 3.25 |
| 21 | T₂₁(B₃M₁S₃D₂) | 9.85 | 50.06 | 8.07 | 4.08 | 7.62 | 2.32 | 37.50 | 3.88 | 3.40 |
| 22 | T₂₂(B₃M₂S₁D₂) | 9.95 | 42.88 | 7.49 | 3.17 | 6.12 | 2.53 | 36.38 | 2.76 | 3.00 |
| 23 | T₂₃(B₃M₂S₂D₂) | 9.95 | 43.54 | 7.89 | 3.24 | 6.31 | 2.45 | 37.50 | 2.84 | 3.10 |
| 24 | T₂₄(B₃M₂S₃D₂) | 9.91 | 45.35 | 7.12 | 3.37 | 7.16 | 2.18 | 34.13 | 3.51 | 3.21 |
| 25 | T₂₅(B₃M₃S₁D₂) | 9.98 | 40.06 | 6.90 | 2.73 | 5.79 | 1.94 | 30.06 | 1.99 | 2.62 |
| 26 | T₂₆(B₃M₃S₂D₂) | 9.99 | 40.67 | 7.27 | 2.78 | 5.82 | 1.89 | 30.99 | 2.06 | 2.70 |
| 27 | T₂₇(B₃M₃S₃D₂) | 9.97 | 42.37 | 6.56 | 2.90 | 5.88 | 1.80 | 28.20 | 2.20 | 3.04 |