

Study on Drying Kinetics for Shredded Ginger through Microwave Heating Followed by Hot Air Drying

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Abstract: This study focused on the drying kinetics for shredded ginger through microwave heating followed by hot air drying. Following objectives were pursued: To study the effect of microwave power level & hot air drying temperature on moisture depletion of shredded ginger sample, To determine the drying rate & drying constant at different MW power levels and HAT. The research contributes to the understanding of the drying behavior of shredded ginger and provides valuable insights into the selection of drying methods to preserve its quality and nutritional value. Notably, the results indicated that the effect of microwave power level can be seen as, the initial moisture content of shredded ginger was 473.4 % (db) which reduces to moisture content level of (435.49% db) for 300W, (409.38 % db) for 450W and (384.80% db) for 600W after pre-heating in microwave. In hot air drying, to attain moisture content value of approximately 50%(db) it takes 9 hours of drying at 60°C whereas approximately same moisture level can be achieved in 6 & 4.5 hours when drying takes place at 70°C & 80°C respectively. This showed that as the air temperature rises, the drying time of shredded ginger reduces. The drying rate increases with increase in power level and hot air temperature. Maximum drying rate for control i.e. 80°C HAT was found to be 3.63 gm of water/gm of dry matter-min and for 600W MWH & 80°C HAT was 4.757 gm of water/gm of dry matter-min. The value of drying constant increases with increasing microwave pre-heating power level and hot air temperature & its value varies from 0.28 to 0.94 min⁻¹.

1. INTRODUCTION

Ginger (*Zingiber officinale*) is a tropical flowering plant that is widely cultivated for its underground rhizomes, which are commonly used as a spice and for their medicinal properties. Ginger is believed to have originated in Southeast Asia, specifically in the regions of India and China. It has a long history of cultivation, dating back over 4,000 years. The spice became highly valued for its flavour, aromatic properties, and medicinal uses, and it played a crucial role in the ancient spice trade. It is a herbaceous perennial plant with a unique and distinctive appearance. It grows upright stems that can reach a height of 3 to 4 feet. The leaves are green, narrow,

and lance-shaped, arranged alternately along the stem. However, it's the underground rhizomes, the thickened underground stems, that are the most sought after and widely used part of the plant. These rhizomes have a tan outer skin and a pale yellow to ivory-colored flesh. The harvesting of ginger typically occurs 8 to 10 months after planting, once the plant has reached maturity. The plant is ready for harvest when the leaves start to turn yellow and the stems begin to dry. Harvesting involves carefully digging up the rhizomes from the soil. This process is done manually, and care is taken to avoid damaging the rhizomes during extraction. After harvesting,

the ginger rhizomes are cleaned and cured. The curing process involves drying the rhizomes in the sun for several days, which helps to develop the characteristic flavour and aroma. Once cured, the ginger can be stored for an extended period or processed for various uses, such as culinary applications, herbal remedies, and the production of ginger-based products like ginger tea or ginger essential oil. India is one of the largest producers of ginger in the world, with a significant portion of the crop being cultivated in the southern states of Kerala, Karnataka, and Andhra Pradesh. Ginger is also grown in other states such as Assam, Meghalaya, and Arunachal Pradesh in the northeast, as well as in states like Odisha, West Bengal, and Uttar Pradesh. The total area under ginger cultivation in India is estimated to be around 150,000 hectares, with an annual production of approximately 1.2 million tonnes. (Bag et al. 2018) Despite its high productivity, ginger cultivation in India is not without challenges. One of the major issues faced by ginger farmers is post-harvest losses, which can occur due to improper harvesting techniques, inadequate storage facilities, and transportation issues. Post-harvest losses of ginger can range from 20% to 40%, depending on the region and the specific practices employed by farmers. Mechanical damage during harvesting and transportation can account for an additional 10-15% of losses. The susceptibility of ginger to mold growth and spoilage if not properly dried and stored can lead to further losses of 5-10%. Improving post-harvest practices, such as proper drying methods, better storage facilities, and pest management strategies, could significantly reduce these losses and improve the income and food security of ginger farmers.

Drying is a crucial step in preserving ginger, offering numerous benefits that enhance its shelf life, maintain quality, and facilitate various applications. By reducing the moisture content, drying inhibits the

growth of microorganisms, such as bacteria and Molds, which are responsible for spoilage. Additionally, the process deactivates enzymes present in fresh ginger that can lead to undesirable changes in flavor, color, and texture over time. Through concentration of Flavors and aromas, drying intensifies the characteristic taste and fragrance of ginger, allowing for more efficient and versatile use in culinary and industrial applications. The removal of moisture also minimizes the risk of oxidation, a process that can negatively impact the color, flavor, and nutritional value of ginger. Furthermore, dried ginger has a reduced weight and volume, making it easier to store, transport, and handle. (Lad et al. 2019)

1.1. Methods used in drying

Microwave Drying: Microwave drying uses electromagnetic radiation to generate heat directly within the material and the microwave oven drying method preserved high nutritional content and was the preferred method. (Ajayi et al. 2017)

Hot Air Drying: Conversely, hot air drying remains a conventional but effective technique, relying on convective heat transfer to remove moisture from ginger. Pre-heating in the context of hot air-drying influences the initial moisture content, affecting the overall drying time and energy consumption. Investigating how ginger behaves during the pre-heating stage in hot air drying is essential for maximizing efficiency and minimizing quality degradation.

1.2. Objectives

The objectives of this research were to determine the main effects of process variables (Microwave power level, Hot air drying temperature, Drying rate, Drying constant) on the quality of dried shredded ginger as well as to optimize the process parameters during MW & HA drying.

2. MATERIAL AND METHODS

2.1. Material

Procurement of fresh shredded ginger (*Zingiber officinale*) took place from the local market in Jabalpur. To facilitate the experimentation process, 200 grams of shredded ginger samples having initial moisture content of 473.4% (db) were meticulously prepared after shredding. This involved a careful and uniform shredding technique to maintain consistency across the samples.

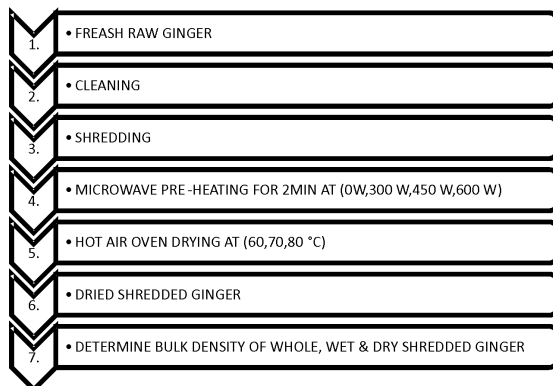
2.2. Methodology

To achieve the study’s objectives, the following experimental plan was implemented. The investigation into the drying kinetics of shredded ginger involved the application of combination of microwave pre-heating followed by hot-air drying.

Table 2.1: Experimental Plans to Study the Combination of the Effects of Microwave Pre heating Followed by Hot Air Drying

| S. No. | Variables | Levels | Measurement parameters |
|--------|--|--------|---|
| 1. | Sample size- 200 g | | Physical properties Moisture content Bulk density(g/cm ³) |
| 2. | Microwave Pre-heating (MW) Power level-0 W,300 W, 450 W, 600 W Exposure time -2 mins | 4 | Moisture depletion |
| 3. | Hot air oven drying (HAT) Temperature - (60,70,80°C) | 3 | Drying kinetics Moisture depletion Drying rate Drying constant |

2.3. Flow chart of the process of drying of shredded ginger



2.4. Physical properties of shredded ginger

2.4.1. Drying Rate

$$DR = \frac{M(t+dt) - Mt}{dt} \tag{2.1}$$

Where

DR = Drying rate [g of water)/g of dry matter)-min]

Mt = Moisture content at time t (db) %

dt = Time of successive measurement (min)

M(t+dt) = Moisture content at time t+dt (db) %

2.4.2. Moisture Ratio (MR)

$$MR = \frac{M - M_e}{M_0 - M_e} \tag{2.2}$$

Where,

M = Instantaneous moisture content (%db)

M₀ = Initial moisture content(%db)

M_e = Equilibrium moisture content

2.4.3. Drying Constant

$$\ln(MR) = -Kt \tag{2.3}$$

Where,

(MR = Moisture ratio

t = Drying time (h)

K = Drying constant (min⁻¹)

2.5. Method employed for drying

2.5.1. Microwave Pre-Heating

Shredded ginger samples were uniformly spread in a microwave-safe container, ensuring an even distribution. The pre-heating experiment was conducted for a duration of 2 minutes, employing three distinct power settings: 300 W, 450 W, and 600 W. This procedure aimed to simulate realistic scenarios, providing insights into the thermal behavior of shredded ginger during pre-heating, laying the groundwork for subsequent drying experiments.

2.5.2. Hot Air Oven Drying

Following the pre-heating phase, shredded ginger underwent hot air drying in a controlled environment using a hot air oven. The shredded ginger samples were evenly distributed on trays within the oven to ensure uniform exposure to the convective heat. The drying experiments were conducted at three distinct temperatures: 60°C, 70°C, and 80°C. The hot air-drying process aimed to eliminate residual moisture content from the pre-heated shredded ginger, contributing to the preservation of its quality attributes. This stage of the experimental design holds particular significance in understanding the interplay between temperature and drying kinetics, laying a foundation for comprehensive insights into the post-harvest processing of shredded ginger.

3. RESULTS AND DISCUSSIONS

3.1. Effect of microwave power levels on initial moisture content of Shredded ginger

Microwave heating of shredded ginger was conducted initially to heat it up, which activates the water molecules in the ginger and accelerates the movement of moisture from the inside to the outside. This pre-heating process helps speed up the drying process while minimizing quality deterioration. Three different power levels (300 W, 450 W, and 600 W) were used to pre-heat the ginger for 2 minutes each. When a 200g sample of fresh ginger with an initial moisture content of 473.40% (dry basis) was heated in the microwave for 2 minutes at these power levels, weight losses of 13.22 g, 22.33 g, and 30.89 g were observed, resulting in moisture levels of 435.49%, 409.38%, and 384.80% at 300 W, 450 W, 600 W respectively.

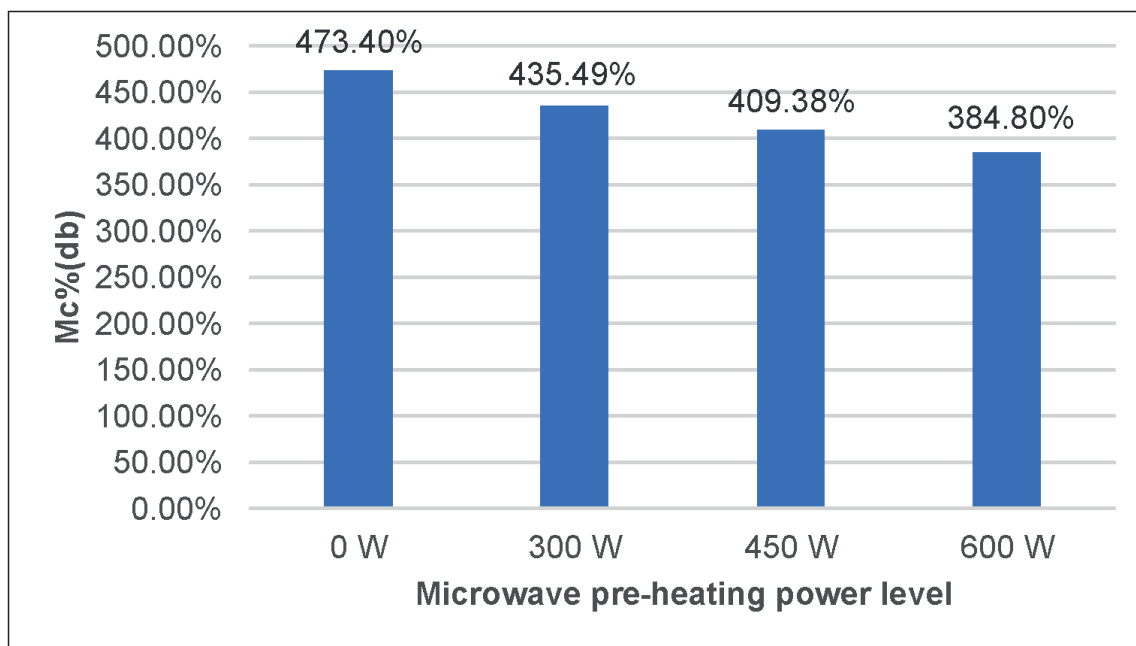


Fig. 3.1: Effect of power level of microwave pre-heating treatment on initial moisture depletion of shredded ginger

3.2. Effect of microwave heating through combine MW & HAOT drying of shredded ginger at different drying air temperature

Figure compares the control sample dried at 60°C HAT to the microwave pre-heated

(MWH) at 300, 450, and 600 watts at 60°C HAT. There is a noted decrease in drying time as power level rises. It can be observed from the figure that to attain moisture level of approximately 45% it takes 10 hours of drying

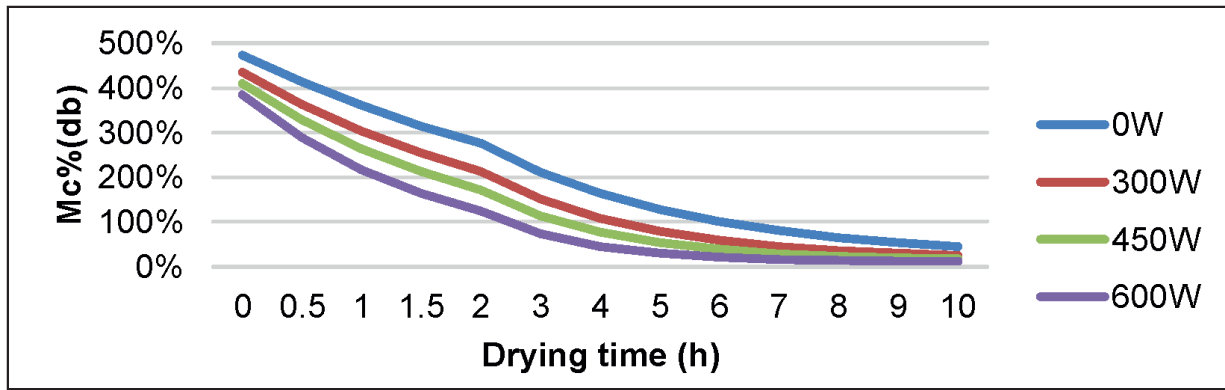


Fig 3.2: Moisture depletion curve of MW heated & control Sample of Shredded ginger for hot air temperature at 60°C

at 0W (control sample) whereas approximately same moisture level can be achieved in 7, 6.5 & 4 hours when drying takes place at 300 W, 450 W & 600 W respectively.

Microwave drying generated volumetric heat in the wet sample, raising the internal temperature and enabling the water to reach the vaporisation point far faster than combination drying could. Preheating the agricultural goods increased their internal vapour pressure, which provided an additional benefit of faster drying when the agri. product were placed in a hot air dryer for the elimination of water during the entire drying process.

3.3. Effects of hot air temperature through combine MW & HAOT drying of shredded ginger at different microwave power levels

Figure compares the moisture depletion for different HAT at 450 W (control sample)

MW power level. It can be observed from the figure that as air temperature increases from 60 to 80°C drying time reduces drastically. To attain moisture level of approximately 50% it takes 9 hours of drying at 60°C whereas approximately same moisture level can be achieved in 6 & 4.5 hours when drying takes place at 70°C & 80°C respectively. It can also be deduced from the figure that drop in moisture content is high at initial stage of drying, as drying proceeds the drop in moisture reduces exponentially at all the drying temperature.

This might be because the outside surface of the shredded ginger has more free moisture. The moisture rate steadily drops after an hour of drying since it may have taken some time for the moisture inside the cell to transfer from the inside to the outside prior to evaporation.

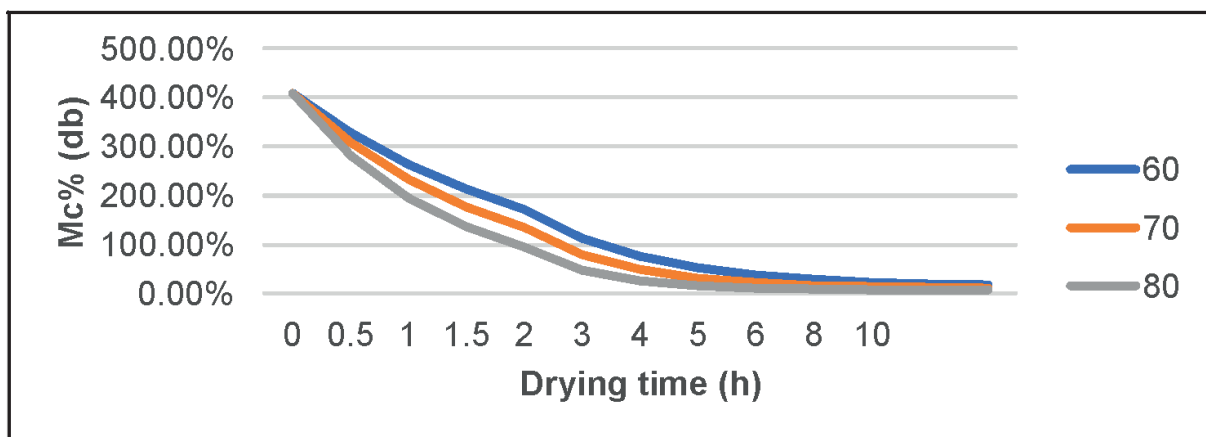


Fig. 3.3: Moisture depletion curve of shredded ginger by hot air drying at 450 W

3.4. Effect of drying parameters on rate of drying

The drying rates increased with the increasing microwave pre-heating power levels and drying temperature. Therefore, microwave power level has an important and positive effect on the drying rates.

3.5. Effect of drying parameters on moisture ratio

Moisture ratio is the ratio between the difference of instantaneous moisture content and equilibrium moisture content to the difference of initial moisture content and equilibrium

moisture content. In which the only variable is instantaneous moisture content. So the value of moisture ratio vary according to the moisture content. The value of natural log of moisture ratio will increase negatively as moisture ratio value decreases.

It can be observed from curve that as heating power level and drying temperature increases, the moisture ratio of shredded ginger decreases.

3.6. Drying constant for drying parameters

I was found that the value of drying constant increase as the microwave pre-heating

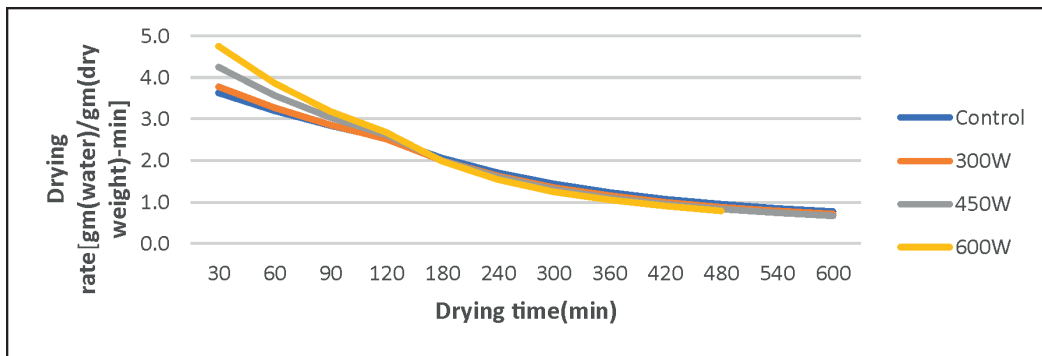


Fig. 3.4 Drying rate curve of MW heated and control samples of shredded ginger by HAOT drying at 80°C

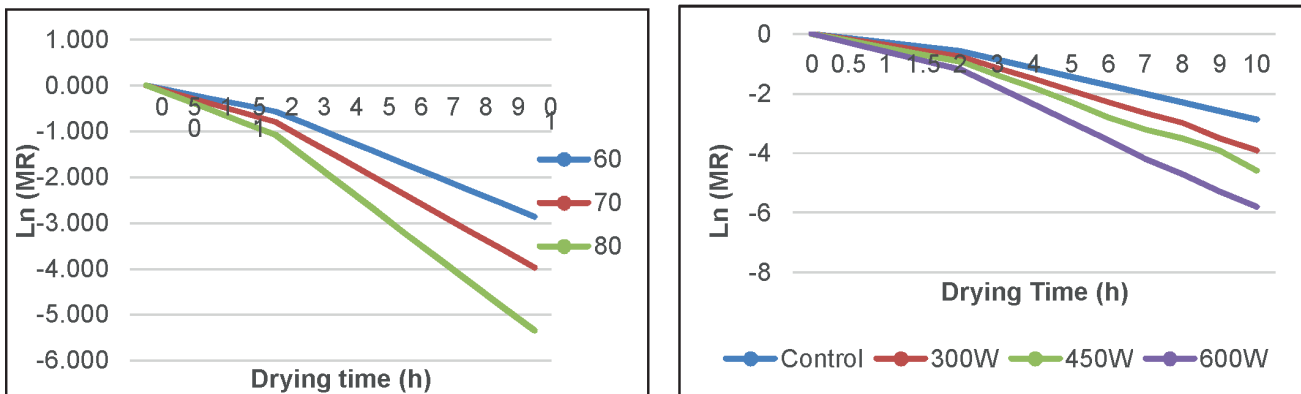


Fig. 3.5 Moisture Ratio (Natural log) trend of shredded ginger

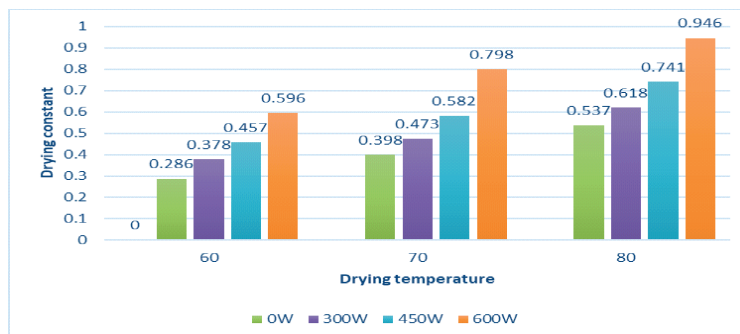


Fig. 3.6 Drying constants for sample dried with microwave pre-heating (300W, 450W, 600W) and with hot air temperature (60°C, 70°C and 80°C)

Power level & hot air temperature increased. Maximum value of drying constant obtained for sample dried at 600 W MWH & 80°C HAOT and minimum obtained for Shredded ginger sample dried at control 60 °C HAOT.

CONCLUSION

1. The effect of microwave power level can be seen as, the initial moisture content of shredded ginger was 473.4 % (db) (control sample) which reduces to moisture content level of (435.49% db) for 300 W, (409.38 % db) for 450W, (384.80% db) for 600 W respectively after pre-heating in microwave.
2. In hot air drying, to attain moisture level of approximately 50% it takes 9 hours of drying at 60°C whereas approximately same moisture level can be achieved in 6 & 4.5 hours when drying takes place at 70°C & 80°C respectively. As air temperature rises, it has been noticed that drying time of ginger reduces.
3. The drying rate increases with increase in power level and hot air temperature. Maximum drying rate [g of water/g of dry matter-min] for control i.e 80°C HAT was found to be 3.63 g of water/g of dry matter-min and for combined microwave hot air drying rate i.e. 600 W MWH & 80°C HAT was 4.757 [g of water/g of dry matter-min].
4. Moisture ratio decreases with increase in microwave pre-heating power level (MWH) and drying temperature.
5. The drying constant for shredded ginger drying varies from 0.28 to 0.94. The value of drying constant increases with increasing microwave pre- heating power level and hot air temperature.
6. The average Bulk densities for raw, wet shredded, and dry shredded ginger are 0.379, 0.458, 0.165 gm/cm³ respectively.

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