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EXPERIMENTAL STUDY ON MICROWAVE DRYING CHARACTERISTICS AND KINETIC OF BUTTON MUSHROOM

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Abstract: **White button mushroom are commonly found worldwide in areas with a humid climatic conditions and is also commercially important cash crop. It is widely collected and eaten due to its various health benefits like preventing many diseases like cancer, diabetes, improving bone health, boosting immune system, etc. Presence of moisture content in button mushroom causes degradation and spoilage is a matter of attention. Drying is the most commercially significant operation in the food industry used for conservation of food material for long duration and retention of nutritional and quality parameters by avoiding microbial spoilage and certain deteriorating chemical reactions. This paper discusses about the drying kinetics and characteristic study of common white button Mushroom in India at different power densities of microwave ranging from 2.4 to 14 W/g. The effect of various drying densities was investigated on drying characteristics and kinetics of butter mushroom. The results suggest that drying densities has significant effect on drying characteristics and kinetics and drying time can be significantly by reduced by increase in microwave density. It was observed that most of the drying occurs in the falling rate period and constant rate period was found to be absent at all power densities. The drying efficiencies of microwave drying of button mushroom were studied and correlated with drying time and different microwave power densities.**

Keywords: **Microwave drying, drying kinetics, button Mushroom, drying efficiency.**

I. INTRODUCTION

The word Mushroom can be applied to any fungus that has a stem, cap and gills. The standard name of the mushroom commonly used in food dressings is Button mushroom or ‘Agaricus bisporus’. It belongs to the kingdom “Fungi” and division “Basidiomycota”. They are predominantly the crop of temperate region and mostly confined to Europe, North America & Eastern Asia but in the recent years they have been successfully introduced in the tropical region as well. Mushrooms are used extensively for cooking in many cuisines notably Chinese, Korean, and European&Japanese. Though neither meat nor vegetable, mushrooms are known as the "meat" of the vegetable world [1]. Most mushrooms sold in markets have been commercially grown on mushroom farms. Raw mushrooms contain 92% water, 4% carbohydrates, 2% protein and less than 1% fat. In a 100 gram amount, raw mushrooms provide 22 calories and are a rich source of vitamin B’s such as riboflavin, niacin and pantothenic acid, selenium , copper and a moderate source of phosphorous, zinc & potassium [2].Some mushrooms are used as possible treatments for various diseases. More particularly their extracts including polysaccharide, glycoprotein and proteoglycan. In some countries, extracts of polysaccharide-K, schizophyllan, polysaccharide peptide, or lentinan are government-registered adjuvant cancer therapies [2]. The health benefits of mushrooms include relief from high cholesterol levels, breast cancer, prostate cancer, and diabetes. They also help in weight loss and increase the strength of the immune system. The export market for Indian Button Mushroom is chiefly the USA, with some quantities going to UAE, Russia, The Netherlands, Germany, UK, Switzerland, Denmark, Israel, Sweden and other countries.

Drying is a simultaneous process of heat and mass transfer widely employed in almost all the manufacturing industries, processing industries, packaging industries and many more. Drying is the removal of water from a product to inhibit the microbial growth and also some chemical reactions that might degrade or rather decompose the product [3]. It increases the shelf life of the product thus making it easy to preserve for a long time without considerable spoilage or harm to the initial quality of product. The most widely used and the oldest drying method is the open sun drying where the sample is subjected to direct sunlight. But the unhygienic conditions such as dust, rodents, and flies may prove to be detrimental to the sample. Also a direct and longing exposure to the solar radiation may even degrade the physical structure, quality, amount of nutrients etc. of the product [4]. A lot many successful drying techniques have been reported in various literatures with uniform drying capability along with hygienic conditions of products but again all of them demand long drying times, high energy requirements and long exposure of product to drying regime. Hence, to overcome these problems and also to preserve the highest quality of product an emerging drying technique known as 'microwave' drying is employed in this paper. Microwave drying is the use of electro-magnetic radiation to bring about the thermal gradient within the product. This is done by vibrating the water to a great extent. The biggest merit of microwave drying is that it brings about rapid evaporation in any of the substance due to its penetrating nature thus reducing the drying time and increasing the drying rate significantly [5].The drying kinetics of mushroom have previously been assessed by many scientist with the help of different drying mechanisms such as- drying with dehumidified air at 20°, 30° and 40°C was carried out by F. Gurtas Seyhan & Ö Evranuz (2013) with Drying temperatures lower than 40°C promoting the production of light coloured mushrooms along with the removal of moisture of up to 87%[6]. S.K.Giri and Suresh Prasad (2007) reported the drying of 6mm to 14 mm slices of mushroom by microwave incorporated with vaccum chamber in the cavity along with wattage as 115-285 W and pressure of 6kPa-23kPa to be as 90%(approx.) [7]. M.K. Krokida (et al 2002) studied air drying of mushroom with sample sizes of 5,10 and 15 mm using air temperature of 65–85 Celcius, relative humidity of 20–40% along with the air velocity of about 1.5–2.5 m/s reporting the moisture removal to be about 91%. Salehi.F. et all (2017) used an infrared-hot air dyrer with infrared lamp power (150, 250 and 375 W), hot air temperature (50, 60 and 70^{o}C) and hot air rate (1, 2 and 3 m/s) and reported the increase in drying rate with the increase in temperature.

All of the above literature suggests that various techniques have been employed to study the drying characteristics of mushroom but still the study on microwave drying of mushroom is not plenty. This paper emphasizes on reducing the drying time and increasing the quality of the product without having any impact on the drying rate. The objective of this paper is to investigate the microwave drying characteristic of mushroom with different microwave intensities.

II. MATERIAL AND METHODOLOGY.

a) Sample preparation

Fresh mushroom was purchased from a local market of Nagpur, Maharashtra, India. The raw mushroom was washed to remove surface dust and other undesired soil matter under running water. The clean mushroom was dried and cut into thin slices with the average thickness of 90±5 mm with knife. The mushrooms were taken and 5 batches each weighing about 20 gm were prepared. The slices were kept in water for about 15 to 20 min and left at ambient temperature for about 15 min after soaking upon filter paper to remove surface moisture and the initial wet weight of each sample was recorded after which they were subjected to microwave heating with continuous weight determination after every 1 minute.

b) Experimental method

The laboratory microwave oven (Koryo, KMS-1711) having the technical feature 230V, 50Hz, with maximum output of 1000 W at 2450 MHz was used for the present study. The microwave had the dimensions of 258×440×334 mm with a rotating glass plate having 245 mm diameter. The fan is provided for air flow in drying chamber and cooling of magnetron. The moisture was removed to atmosphere through the opening at the back side of the oven wall through this fan. The oven had a control panel to regulate microwave output power levels. The drying trials were carried out at five different microwave power densities of 2.4, 4.6, 7.6, 10 and 14 W/g. The moisture loss in the sample was recorded at regular time intervals by using a digital weighing balance. The drying trials were conducted until the final moisture content reached a constant value. The experimental data was tabulated with respect to different temperature ranges and graphical representation of drying rate vs time, moisture ratio vs time and moisture ratio vs drying rate was prepared.

The initial moisture content of fresh mushroom was determined three times so as to obtain the reasonable average and was found out to be 89.3-89.5% (wet basis). Accurately weighed sample of mushroom was placed in the laboratory oven at the constant temperature of 60ºC. The weight loss was recorded until the constant reading was obtained and calculated in % wet basis by following equation:

$$M_{initial}\ (\%\ \text{Wet basis}) = \frac{W_w - W_d}{W_w} \times 100 \qquad (1)$$

Where, $M_{initial}$ is the initial moisture content of mushroom on % wet basis, W_w and W_d is the wet and dry weight of material in kg.The drying rates were calculated by the following equation:

$$\frac{dM}{dT} = \frac{M_o - M_t}{dt} \qquad (2)$$

Where, $\frac{dM}{dt}$ is drying rate (kg water/kg of wet material per min), t is time (min), M_o and M_t are the initial and final moisture content at time t on wet basis respectively

The moisture ratio of the material to be dried was calculated from experimental drying data by following equation:

$$MR = \frac{M_t - M_e}{M_o - M_e} \qquad (3)$$

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Where, M_t,M_o and M_e are the moisture content at any time 't' , initial, and equilibrium time on wet basis (respectively). The moisture ratio can be simplified as:

$$MR = \frac{M_t}{M_o} \quad (4)$$

III. RESULTS AND DISCUSSION

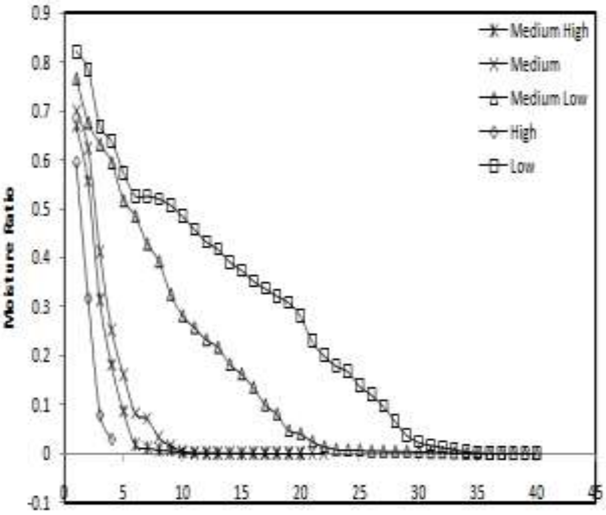

Figure 1. Variation of moisture ratio vs time (min) at different power intensities of microwave.

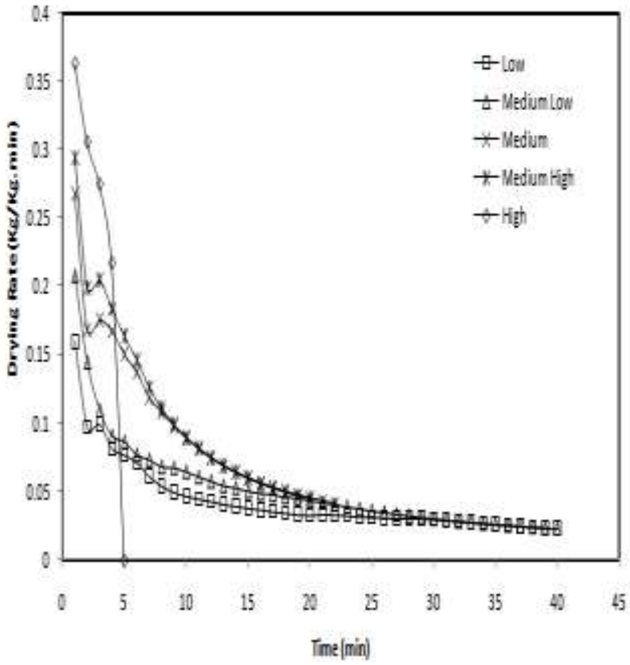

Figure 2. Variation of drying rate (kg/kg min) vs time (min) for different power intensities of Microwave

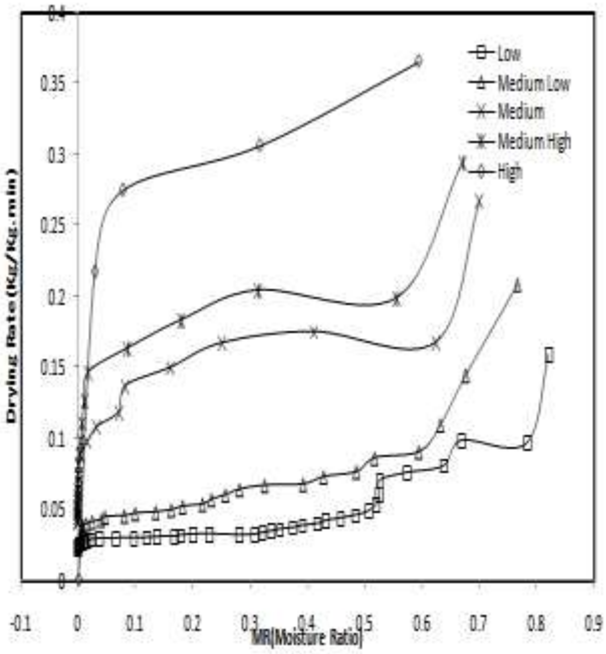

Figure 3. The graph of moisture ratio vs drying rate for different Microwave intensities.

The graphical curve of moisture ratio with time at different microwave power intensities is shown in Figure 1. It was observed that moisture ratio exponentially decreased with drying time for every power intensity. The drying time required to reach from initial moisture content of 89% to final moisture content up to 9% (wet basis) was found to be 38, 37, 14 and 12 min at the power densities of 2.4, 4.6, 7.6 and 10.8 W/g respectively. Interestingly at the power density of 14 W/g the product after the 4^{th} minute started to decompose due to very high temperature. At high power densities the quick absorption of electro-magnetic energy by the product causes rapid evaporation of water, resulting in decrease in the moisture ratio and speeding up of the drying process, thus shortening the drying time up to 70%.

The graphical curve of drying rate (kg/kg min) vs time at different power intensities is shown in Figure 2. It was observed that the drying rate for the high power intensity (14 W/g) decreased exponentially, while for the rest of the power intensities almost the same graph can be observed after 20 min. This suggests that more or less the drying rate after 20 mins remains almost constant and just experiences a slight drop. This is mainly because a significant amount of the moisture is removed during the initial period [8]. The graph suggests that at all the power intensities except high the drying rate was good and almost coincided after 25 minutes.

The graphical curve of drying rate vs moisture ratio is depicted in Figure 3. A kind of non-linear relationship was observed in the graph. The drying rates increased with the increase in the microwave intensities, this can be due to the fact that the energy given off by the waves resulted in a high volumetric heat generation which in turn provides high product temperature along with a larger driving force improved mass transfer rate and hence rapid evaporation of the water molecules. Drying rates initially increased and then decreased slightly after which they plateaued with a reduction in moisture content for all power densities. This was due to the fact that free moisture is available, and can be easily removed at the initial stage of drying after which when critical moisture content is reached the drying rate decreases this continues until the equilibrium moisture content is reached [10]. Materials having high moisture content especially fleshy food materials like Mushroom upon being heated at low temperature show a constant drying rate regime. In this paper, all of the drying was carried in falling drying rate period for the different power densities of the microwave. The falling rate period indicates that mechanism of drying occurring in the product is mainly diffusive [11]. This can again be due to the fact that microwave energy gave rise to high amount of volumetric heat resulting in high rates of mass transfer and its driving forces.

IV. CONCLUSION

The microwave drying characteristics of button Mushroom were studied at different microwave power densities ranged from 2.4 to 14 W/g. It was observed that microwave drying yields a better product due to less heat exposure time as compared to conventional drying techniques with significant reduction in drying time. The entire drying process was carried in a falling rate period and the drying time could be reduced for up to 70% with the increase in power density. The drying rate was found to be moisture ratio dependent and was found to be high initially due to presence of free moisture content. The drying rate retarded further due to critical moisture content. The drying efficiencies were observed to be high at the initial stage of drying and decreased as the drying proceeds and then remained constant. Initially the moisture ratio decreased slightly at low temperatures but as the temperature increased the moisture ratio decreased exponentially about (60% to 65%) at high values of microwave power densities.

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