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Extended Abstract

The Evaluation of Quality Parameters and Drying Efficiency of Button Mushroom in Hybrid Microwave-Hot Air Dryer

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Abstract

In this study, the button mushroom (agaricus bisporus) as a whole in a combined microwave-hot air dryer in two status of power density: fixed and variable, three levels of initial power density (1.5, 2 and 2.5 W/g) and three levels of hot air temperature (23, 50 and 70 ºC) were dried. Drying efficiency and the final dried product quality (color and rehydration ratio) were evaluated. The highest drying efficiency (44.44%) was obtained with 1.5 fixed power density and 23 °C. The results of color parameters showed that the dried product in constant power density status had better appearance (color) than the variable mode and also increased power density levels and reduced the air temperature increased the color changes and decreased final products quality. Also the dried product with constant power density in compared with variable power density and using the hot air in compared with environmental air had higher rehydration ratio.

Keywords: Color Parameters, Drying Time, Power Density, Rehydration Capacity

Introductıon

Fresh mushrooms are one of the extraordinarily perishable and its shelf life is only about 24h at ambient conditions (Giri & Prasad, 2007). Therefore processing the mushroom after harvest for maintaining long time is necessary. Drying is one of the oldest methods of preserving foods. Hybrid microwave-hot air has a lot of benefits such as volumetric heating, high thermal efficiency, shorter drying time and improved product quality and therefore it is developing to use for drying of foods. The newest study for evaluating the drying kinetic of apple slices in the hybrid microwave-hot air and demonstrating its benefits was done by Horuz *et al*. (2018).

In conventional microwave drying method, a fixed microwave power was used during the drying process. But the water of the product evaporated and mass of product decreased over the time that resulted microwave power density (MPD) increased during the drying process. The MPD (W/g) was defined as the power to be applied to the product per unit mass of product. Increasing the power density, especially in the end of process, represents that the microwave energy is higher than required energy to evaporate of water. The excess

energy absorbed by product and converted to heat energy and sharply increased the product temperature (Li *et al.*, 2010; Kone *et al.*, 2013).
The literature review demonstrated that mostly previous studies have been done with variable microwave power density. Therefore, in this study, the experiments with constant and variable MPD and different hot air drying temperature in the hybrid microwave-hot air dryer were done to evaluate these effective parameters on drying efficiency, the final dried product quality (color and rehydration ratio) and drying time.

Material and methods

Button Mushrooms (Agaricus bisporus) with 89.65% the initial moisture content of mushrooms based on wet basis were used. The microwave-hot air prototype drier was designed in Uremia University (Hazervazifeh *et al.*, 2016). Product mass (accuracy of ±1 g) was recorded by a load cell at 3 min of time interval. Air temperature was set up in three levels: 23 (environment temperature), 50 and 70 °C. The inlet air flow velocity was 0.25 m/s in all experiments. In this study, the mushrooms with same diameter (4±0.15 cm) and color were selected and located on tray in the dryer.

The MPD was applied in two statuses: variable MPD and almost constant MPD (Figure 1). In the variable power density, microwave power maintained constant during drying process and with decreasing the moisture content of product, the power density was increased (Figure 1a). In the constant power density with removing of the moisture content, the microwave power decreased to maintain the constant MPD. In this method during the drying process, microwave power was reduced by 20% with concerning the moisture content of product for preventing to reach the high power density (Figure 1b). In both method the drying process started with three levels of MPD of 1.5, 2, 2.5 W/g. All experiments started with 500 W of microwave power and for obtaining to 1.5, 2 and 2.5 W/g in each experiment 333.3, 250 and 200 g of mushroom were used, respectively.

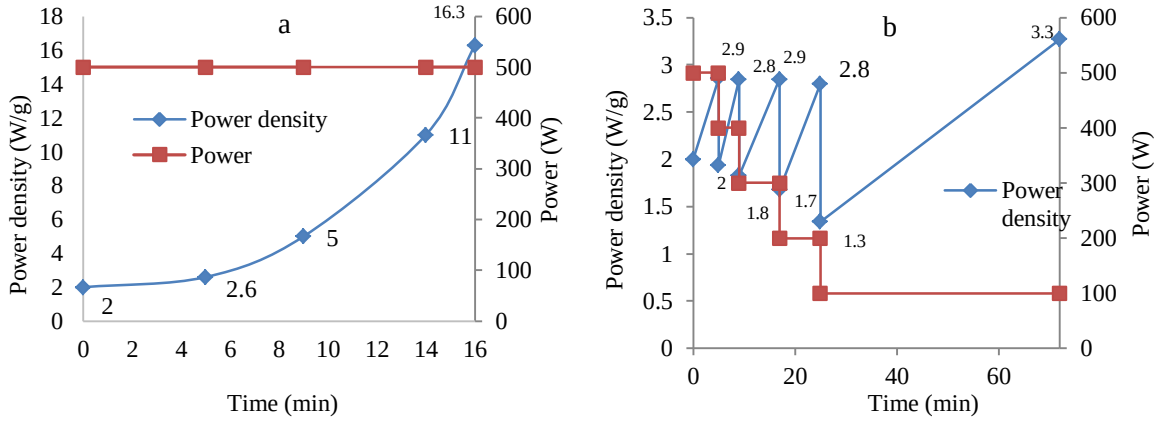

Figure 1. Variations of microwave power and power density with time: a) variable power density, b) almost constant power density, (T=70 °C and initial microwave power density 2 W/g)

Color measuring of fresh and dried mushroom samples has been done by investigated machine vision system and image processing algorithm (Sharifian *et al.*, 2013). The total color difference (ΔE) and browning index (BI) were used as quality index and calculated with the Following equations:

$$\Delta E = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2} \quad (1)$$

$$BI = \frac{[100(x-0.31)]}{0.17} \quad (2)$$

$$x = \frac{(a^* + 1.75L^*)}{(5.64L^* + a^* - 3.012b^*)} \quad (3)$$

For measuring the rehydration ratio, submerging method in distilled water with 23±2 ºC was used. Energy consumption of the hybrid oven was measured by a digital watt-meter and the drying energy efficiency was calculated by the flowing equation:

$$\eta = \frac{W_{eva} \times \lambda}{E_1 + E_2} \times 100 \quad (4)$$

Where η drying energy efficiency, E_1 is the total energy was used by hot air (kJ), E_2 the total energy used by microwave (kJ), W_{eva} the mass of water evaporated (kg), λ latent heat of water (2260 kJ/kg).

Results and discussion

The results indicated that with increasing the power density and air temperature, the drying time decreased (Table 1). The highest drying time 127.3 min was obtained with 1.5 fixed power densities and 23 °C air temperature and the lowest drying time 16 min was observed with 2.5 variable power density and 70 °C air temperature of drying condition.

The highest total color deterioration were happened in 23 °C and varied from 31.50 to 41.08 for ΔE and 118.5 to 197.1 for BI in variable power density and varied from 23.50 to 31.27 for ΔE and 84 to 111.71 for BI in fixed power density. The color deterioration results indicated that the drying with fixed power density had lower color changes than variable state and increasing the power density increased the color changes and increasing the air temperature decreased them. The lowest color deterioration was found 10.10 for ΔE and 42.32 for BI with highest air temperature of 70 °C and lowest MPD of 1.5 W/g with constantan status. The results of drying efficiency expressed that drying with ambient temperature had highest drying efficiency. Drying with ambient temperature and 1.5 fixed power density had highest drying efficiency (44.44%) and with 1.5 fixed power density and 70 °C had lowest drying efficiency (9.77%), (Table 1). The same result was found by Horuz *et al.* (2018).

Table 1. Drying time, drying efficiency and rehydration ratio

Power density status	Temperature	Power density	Drying time (min)	Drying efficiency	Rehydration ratio
Variable	23	1.5	81^{cd}	30.86^{b}	2.13^{bc}
		2	52^{fg}	30.72^{ab}	2.163^{bc}
		2.5	35^{hi}	37.67^{abc}	2.203^{b}
	50	1.5	56^{fg}	17.82^{bc}	2.15^{bc}
		2	42^{gh}	19.25^{bcd}	2.12^{bcd}
		2.5	24^{ij}	24.53^{bcde}	2.183^{b}
	70	1.5	52^{fg}	15.65^{bcd}	2.17^{bc}
		2	33.3^{hi}	16.40^{b}	2.184^{b}
		2.5	16^{j}	26.96^{a}	2.196^{b}
Fixed	23	1.5	127.32^{a}	44.44^{e}	1.79^{e}
		2	102.66^{b}	$45.41d^{e}$	1.83^{de}
		2.5	83.33^{cd}	36.83^{cde}	1.87^{cde}
	50	1.5	96^{bc}	14.22^{ab}	2.26^{ab}
		2	84^{cd}	13.05^{abc}	2.28^{ab}
		2.5	65.4^{ef}	12.91^{abc}	2.34^{ab}
	70	1.5	90^{bc}	9.77^{ab}	2.27^{ab}
		2	71^{de}	10.14^{abe}	2.30^{ab}
		2.5	58^{ef}	10.79^{a}	2.51^{a}

Means followed by different letters within a column are significantly different ($P \leq 0.05$).

Conclusion

Drying kinetic of whole mushroom in a hybrid microwave-hot air dryer was studied. Drying time of whole mushroom decreased with changing microwave power status form fixed to constant, increasing microwave power and air temperature. The lowest drying efficiency was observed in 50 and 70 °C of hot air temperature and with fixed power density. The lowest color deterioration was found 10.10 for ΔE and 42.32 for BI with 70 °C and 1.5 fixed power density of drying conditions. Increasing the power density and air temperature increased rehydration ratio of dried product.

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