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Article

Effect of Microwave-Based Dry Blanching on Drying of Potato Slices: A Comparative Study

Megaswana Guruprasad, Jeevitha Gada Chengaiyan,* Faraz Ahmad, Shafiul Haque, Esra Capanoglu, and Deependra Rajoriya

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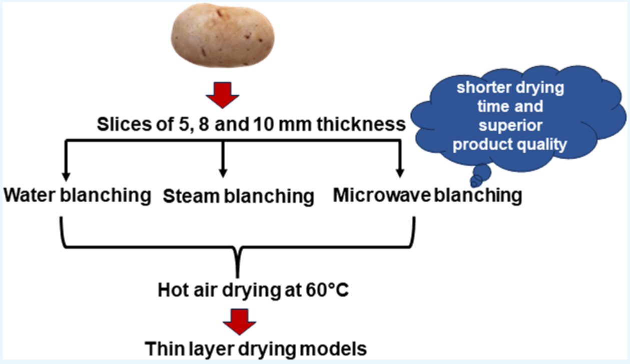
ABSTRACT: Microwave (MW)-based dry blanching can inactivate oxidative enzymes like peroxidase (POD) and polyphenol oxidase (PPO) rapidly and retain a higher amount of water-soluble nutrients, like ascorbic acid. This study compared the MW-based dry blanching of potato slices of various thicknesses (5, 8, and 10 mm) with conventional methods (water and steam blanching). The time required for water and steam blanching was longer than that required for MW blanching. Potato slices of 10 mm thickness required a longer blanching duration compared with slices of a lesser thickness (5 and 8 mm). The MW-blanched samples (77.37−83.5%) retained a higher content of ascorbic acid, followed by steam-blanched (69.15−74.92%) and water-blanched (67.18−71.54%) samples. The Page, modified Page, Midilli−Kucuk, and Hii, Law, and Cloke models predicted the thin layer drying of potato slices (5 mm thickness) better with a higher coefficient of determination values (0.9607−0.9976) compared to Fick's and Exponential models (0.8942−0.9444).



1. INTRODUCTION

Potato (*Solanum tuberosum* L.) tuber is an underground stem of vegetative propagation whose cultivation is believed to date back 8000 years. It is used as a staple food, animal feed, and cash crop and also acts as a raw material to provide starch for many industries in almost 160 countries.[1] Potato is also called the "vegetable king" and can be consumed as chips, fries, and in many other dehydrated forms. Potatoes are processed into frozen French fries, chips, table stock, and shoestrings.[2] They also serve as a primary or secondary source of food and nutrition for low-income households. Potatoes are a rich source of complex carbohydrates, dietary fibers, minerals, ascorbic acid, and other photoactive compounds. Potatoes have the highest satiety index of all plant foods. Potatoes also contain antioxidants like ascorbic acid and polyphenols that, in turn, can play a role in preventing age-related diseases.[3]

Peroxidase (POD) and polyphenol oxidase (PPO) are the two major oxidative enzymes responsible for browning in vegetables and fruits. These enzymes are present in appreciable amounts in potatoes and can initiate undesirable changes in product quality during processing. Blanching is a pretreatment method generally carried out to inactivate various oxidative enzymes present in fruits and vegetables.[4] Even though reports on MW-based blanching of red bell pepper,[5] green asparagus butt segment,[6] orange-fleshed sweet potato slices,[7] *Moringa oleifera* leaves,[8] and Indian gooseberry[9] are available, studies on dry blanching of potatoes are limited. A few reports on low-temperature blanching of mashed potatoes[10] and water and steam blanching of potato slices[11,12] have been published. However, the effect of the thickness of potatoes on blanching and a comprehensive study of the effect of water, steam, and microwave (MW) blanching on the hot air drying of potatoes have not been reported. Hence, the major objective of this study was to employ MW-based dry blanching for enzyme inactivation in potato slices of different thicknesses (5, 8, and 10 mm) and to compare it with conventional water and steam blanching methods. The effects of water, steam, and MW blanching on the hot air drying characteristics of potato slices (5 mm thickness) were also studied.

2. MATERIALS AND METHODS

2.1. Materials. Potatoes (moisture content 82.44 ± 0.9% on a wet basis) were purchased from the local market and stored at 4 ± 1 °C until further usage. The raw material was

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procured from the same source, and potatoes of the same sizes were used in the study.

2.2. Methods. *2.2.1. Sample Preparation.* The potatoes used in this study were thoroughly washed with a continuous stream of tap water, and slices of various thicknesses, such as 5, 8, and 10 mm, were prepared and used in the study.

2.2.2. Blanching Methods. 2.2.2.1. Water Blanching. Potatoes (20 g) were transferred to a vessel containing hot water (1:3) maintained at 90 ± 2 °C for 0.5−2.5 min. After being blanched, the potato samples were cooled immediately to room temperature (28 °C) by dipping them in cold water for 5 min. By using filter paper, the surface moisture of slices was removed and subjected to various analyses.[5]

2.2.2.2. Steam Blanching. Using an autoclave, potato slices of various thicknesses were subjected to steam blanching by exposing them to steam for 2−3 min. The steam-blanched potato samples were dipped in cold water for 5 min for immediate cooling to room temperature. The surface moisture of the blanched samples was removed by wiping them with filter paper and further subjected to various analyses.

2.2.2.3. Microwave Blanching. Microwave blanching was performed in a domestic microwave oven (MH2044DB, LG, Mumbai, 2450 MHz, 800 W) at a 26.7 W/g intensity for up to 1 min. The samples were kept on a glass Petri plate, which was placed on the periphery of the turntable to improve the uniform power distribution over the potato samples during rotation. To facilitate more even power distribution, the position of the plate was marked on the turntable, and it was maintained at the same level to minimize the variation in the following experiments. The blanched potato samples were cooled immediately to room temperature by blowing air to minimize product quality deterioration.[5]

In all of the experiments, the end point of blanching was a 90% reduction in POD activity.

2.2.3. Methods Used for Analysis. 2.2.3.1. Peroxidase (POD) Assay. By using 0.1 M sodium phosphate buffer at pH 7, potato slices were homogenized in a ratio of 3:1. This was followed by filtration using a muslin cloth and centrifugation at 6000 rpm for 20 min at 4 °C. The supernatant was collected and used for the enzyme assays.

Fifty microliters of the enzymatic (potato) extract was added to the substrate solution containing 1.0 mL of phosphate buffer (pH 6), 1 mL of 3 mM H_2O_2, and 1.0 mL of 15 mM guaiacol. The increase in OD was monitored at 470 nm continuously for 5 min using an ultraviolet (UV) visible spectrophotometer (UV-1280, Shimadzu, Japan). A graph was plotted relating optical density (OD) with time, and the linear portion was considered for slope determination. POD activity was expressed as ΔAbs_{470}/min.g sample.[13]

2.2.3.2. Polyphenol Oxidase (PPO) Assay. The reaction mixture contained 1000 μL of catechol as the substrate and 40 μL of the enzyme extract, and OD was monitored at 411 nm.[14] PPO activity was determined by using a graph relating OD with time and expressed as ΔAbs411/min.g sample.

2.2.3.3. Moisture Content Analysis. A gravimetric method was used to determine the moisture content of samples. Potato samples were dried at 105 °C for 3 h and expressed on a wet basis.[15]

2.2.3.4. Ascorbic Acid Assessment. Potato extract for ascorbic acid determination was prepared by homogenizing 10 g of potato slices with 3% m-HPO_3 (100 mL), followed by filtration using a muslin cloth. The filtrate was subjected to centrifugation at 6000 rpm for 20 min at 10 °C. The 2,6-dichlorophenol indophenol titrimetric method was used for the quantification of the ascorbic acid content and expressed as mg of ascorbic acid/g of sample on a dry basis.[16]

2.2.3.5. Hot Air Drying. The drying of blanched potatoes was carried out in a temperature-controlled hot air oven (ILE, Chennai) at 60 °C for 6 h. The samples were transferred to the tray and evenly spread. Frequently, the tray in the dryer had to be rotated to ensure uniform exposure of the samples to hot air. After removal from the dryer, the samples were cooled to room temperature and locked in airtight polythene pouches to prevent the absorption of atmospheric moisture.

2.2.3.6. Rehydration Characteristics. Dried potato slices were rehydrated in boiling water for 10 min.[17] This allows measurement of the maximum amount of water that the product can absorb after immersion in water. This value depends upon the damage to the cells of food material during drying. The rehydration ratio is calculated by taking the ratio of the weight of the rehydrated potato slices to the weight of the dehydrated potato slices.

$$\text{coefficient of rehydration} = [W_R \times (100 - A)]/[(W_D - W_U) \times 100] \tag{1}$$

where W_R is the weight of rehydrated material, A is the initial moisture content of the potato, W_D is the weight of the dried sample, and W_U is the moisture content of the dried sample.

2.2.3.7. Starch Solubility and Swelling Power. The swelling power and solubility index of potato slices were determined by following the method reported by Leach et al.[18] with slight modifications. The dried slices were ground into powder using a domestic blender. Two percent starch dispersions were taken in a glass beaker covered with aluminum foil and exposed to 60 °C for 30 min by keeping it in a water bath with stirring at regular intervals. This was followed by centrifugation at 4500 rpm for 15 min, and the weight of the pellet (W_p) was determined. The supernatant and pellet were dried at 105 °C for 24 h. The weight of dry solids in the pellet (W_{ps}) and supernatant (W_s) was calculated.

$$\text{swelling power} = W_p/W_{ps} \tag{2}$$

$$\text{solubility} = W_s/\text{dry mass of the whole starch sample} \tag{3}$$

2.2.3.8. Estimation of Drying Rate Constant. A plot of drying rate (dm/dt) versus average moisture content (M) was drawn[19] for the slices blanched by different methods and dried using hot air to calculate the drying rate constant (k).

$$dm/dt = -kM \tag{4}$$

2.2.3.9. Thin Layer Drying Models. The most widely used thin layer models, such as Exponential, Page, modified Page, Fick's, Midilli−Kucuk, and Hii, Law, and Cloke models, were selected to check their suitability in describing the thin layer drying characteristics of potato slices. The simple exponential model assumes that internal resistance to moisture movement and moisture gradients are negligible, and only surface resistance is considered.[20] The exponential model is given as follows

$$\frac{M_t - M_e}{M_0 - M_e} = \text{MR} = \exp(-kt) \tag{5}$$

where M_t, M_e, and M_0 are the moisture content (%) at time t (min), equilibrium, and initial condition, respectively; MR is the moisture ratio, and k is the model constant.

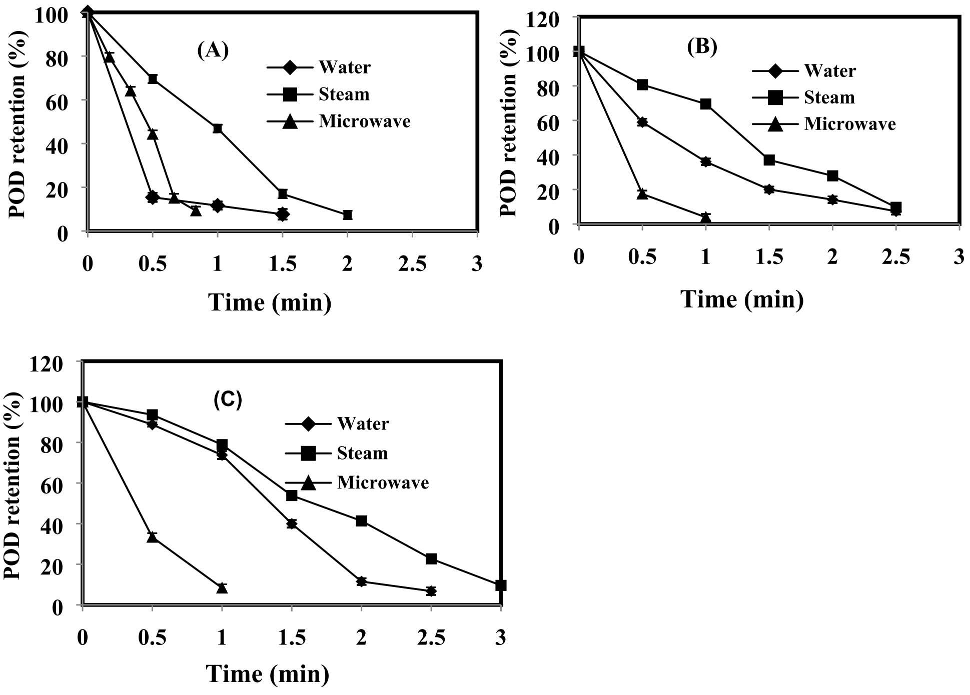

Figure 1. Effect of blanching on peroxidase retention in (A) 5 mm slice, (B) 8 mm slice, and (C) 10 mm slices.

The Page model[21] is a simple empirical modification of eq 5 that involves another drying parameter "n". This is developed to minimize the drawbacks of the exponential model, like overpredicting the initial stages and underpredicting the later stages of drying, as shown below

$$\mathrm{MR} = \exp(-kt^n) \quad (6)$$

where n is the model constant.

The inclusion of another empirical coefficient "d" (half thickness) in eq 6 results in the modified Page model[22] as follows

$$\mathrm{MR} = k\,\exp(-t/d^2)^n \quad (7)$$

A simplified solution of Fick's diffusion equation, which is valid for longer drying time[23] is given as

$$\mathrm{MR} = k\,\exp(-nt/d^2) \quad (8)$$

where d is the half thickness of the sample.

A semiempirical Midilli–Kucuk model[24] that considers no resistance to moisture transfer was also used to study the drying kinetics as given below

$$\mathrm{MR} = a\,\exp(-kt^n) + bt \quad (9)$$

where a and b are the model coefficients.

The Hii, Law, and Cloke model[25] is a semitheoretical model that includes a tempering period given as

$$\mathrm{MR} = a\,\exp(-kt^n) + c\,\exp(-gt^n) \quad (10)$$

where c is the model coefficient and g and n are model constants.

Assuming that the initial moisture distribution in the material is uniform at $t = 0$, shrinkage of the material does not significantly alter the product shape, and the drying time is long, Fick's second equation for diffusion in the slab[26] is given as

$$\frac{M - M_e}{M_0 - M_e} = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp\left\{-(2n+1)^2\pi^2\frac{D_{\mathrm{eff}}t}{4d^2}\right\} \quad (11)$$

where D_{eff} is effective diffusivity ($\mathrm{m^2/s}$) and d is the half thickness of the sample (m).

The logarithmic form of eq 9[27] can be written as follows

$$\ln\left(\frac{M - M_e}{M_0 - M_e}\right) = \ln\left(\frac{8}{\pi^2}\right) - D_{\mathrm{eff}}t\left(\frac{\pi}{2L}\right)^2 \quad (12)$$

The diffusivity was calculated using eq 10 by considering the final moisture content of the sample as the equilibrium moisture content "M_e".[28]

2.2.4. Statistical Analysis. The data presented in this article are the mean values of triplicate data obtained during the same trial. A one-way analysis of variance using the Tukey multiple comparison method was used to observe significant ($p < 0.05$) differences in the tested parameters for different methods using Minitab 21.0 software (2021 Minitab, Inc.). The results of means ± standard deviations are reported. Modeling was carried out using the SOLVER tool based on the iteration method in a Microsoft Excel spreadsheet (Microsoft Office 2021).

3. RESULTS AND DISCUSSION

3.1. Peroxidase Inactivation. POD and PPO contents in potatoes were found to be 930 U/g FW and 105 U/g FW, respectively. Inactivation of POD to 10% of its initial activity is essential to minimize the undesirable changes in the quality of the product, which is to be further processed. Potato slices of different thicknesses (5, 8, and 10 mm) were exposed to water, steam, and MW blanching for different durations. Samples were withdrawn at appropriate intervals and analyzed for the POD and PPO activity. As can be seen from Figure 1, the time required for the 90% peroxidase inactivation of 5 mm slices was the least for MW (0.83 min), followed by water (1.5 min)

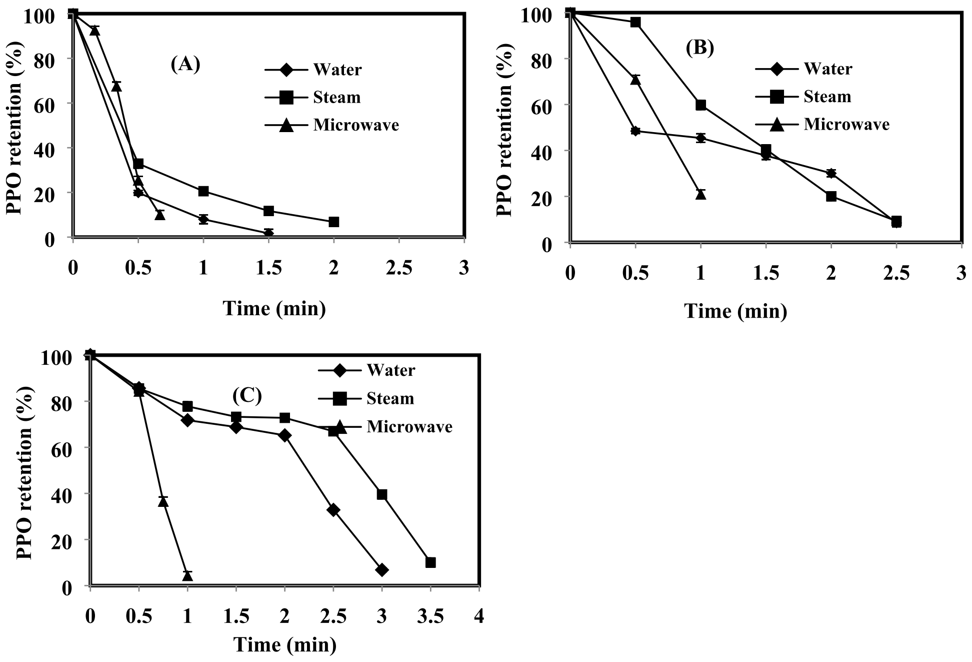

Figure 2. Effect of blanching on polyphenol oxidase retention in (A) 5 mm slice, (B) 8 mm slice, and (C) 10 mm slices.

and steam blanching (2 min). The water-, steam-, and MW-based blanching of 8 mm potato slices showed 90% POD inactivation at 2.25, 2.5, and 0.85 min, respectively. When 10 mm slices were also subjected to the water, steam, and MW treatments, the time required for the desired level of enzyme inactivation was 2.5, 3.0, and 1 min, respectively. The quicker inactivation of POD is attributed to the quick heating of the material compared to water and steam blanching. Desmond et al.[29] also reported optimum water blanching conditions for 10 mm potato slice thickness at 80 °C for 3 min. The infrared blanching of 4 and 8 mm potato slices required a longer duration (18 and 21 min) compared to water (7 and 9 min) and MW blanching (5 and 7 min), respectively.[30]

3.2. Polyphenol Oxidase Inactivation. PPO inactivation trend in potato slices of various thicknesses (5, 8, and 10 mm) was similar to POD inactivation curves, but the inactivation of PPO was quicker (Figure 2). Bingol et al.[31] reported that infrared-based blanching of 9 mm potato French fries resulted in the complete inactivation of PPO in 3 min.

3.3. Effect of Enzyme Inactivation on Product Quality. *3.3.1. Moisture Content.* The moisture content in unprocessed potato samples was found to be 82.44 ± 0.9% on a wet basis. This was compared to blanched potato slices of various thicknesses (5, 8, and 10 mm). The moisture content of water-blanched samples was higher than that of steam-blanched samples as the blanching method involves direct blanching in hot water followed by cooling (in cold water), whereas in steam blanching, the samples are exposed to steam and then subjected to a cooling process (Table 1). During the MW-based dry blanching, the observed moisture loss of about 5−6% is advantageous if the subsequent step is drying.

3.3.2. Ascorbic Acid Retention. The ascorbic acid content in unprocessed potato samples was found to be 38 ± 0.89 mg/100 g on a wet basis. Han et al.[32] also reported ascorbic acid content in different potato cultivars ranging from 16 to 46 mg/100 g wet basis. In 5 mm potato slices, the ascorbic acid content in water-, steam-, and MW-blanched slices was 27.19 ± 0.29, 28.28 ± 0.28, and 31.73 ± 0.21 mg/100 g on a wet basis, respectively. The ascorbic acid content in water-, steam-, and MW-blanched 8 mm slices was 26.06 ± 0.16, 27.65 ± 0.21, and 31.52 ± 0.24 mg/100 g on a wet basis, respectively. The water-, steam-, and MW-blanched potato slices of 10 mm thickness contain ascorbic acid content of 25.53 ± 0.21, 26.28 ± 0.14, and 29.40 ± 0.13 mg/100 g wet basis, respectively (Table 2). The MW-blanched samples retained a higher amount of ascorbic acid, followed by steam- and water-blanched samples. Due to the higher solubility of ascorbic acid in water, the loss was found to be higher in the case of water-blanched samples than in steam-blanched samples. The poor retention of ascorbic acid is attributed to the loss of water-soluble ascorbic acid during the heating and cooling steps

Table 1. Effect of Blanching on Moisture Content

	moisture content (%)		
blanching	5 mm slice	8 mm slice	10 mm slice
water	86.22 ± 0.11[a]	86.58 ± 0.21[a]	87.18 ± 0.24[a]
steam	84.89 ± 0.23[a]	84.75 ± 0.14[a]	85.15 ± 0.18[a]
microwave	76.38 ± 0.17[a]	76.96 ± 0.10[a]	77.37 ± 0.16[a]

[a] Note: Each result was a mean ± standard deviation of triplicate experiments. Mean values that do not share the same letter in the same column are significantly different ($p < 0.05$).

Table 2. Effect of Blanching on Ascorbic Acid Content[a]

	ascorbic acid content (mg/100 g) wet basis		
method of blanching	5 mm thickness	8 mm thickness	10 mm thickness
water	27.19 ± 0.29[b]	26.06 ± 0.16[b]	25.53 ± 0.21[b]
steam	28.28 ± 0.28[b]	27.65 ± 0.21[b]	26.28 ± 0.14[b]
microwave	31.73 ± 0.21[b]	31.52 ± 0.24[b]	29.40 ± 0.13[b]

[a] Ascorbic acid content in an unprocessed sample is 38 ± 0.89 mg/100 g wet basis. [b] Note: Each result was a mean ± standard deviation of triplicate experiments. Mean values that do not share the same letter in the same column are significantly different ($p < 0.05$).

involved during water and steam blanching. The ascorbic acid retention in infrared- and MW-blanched potato slices (4 and 8 mm thickness) was similar.[30]

3.3.3. Effect of Enzyme Inactivation on Drying. The blanched potato slices were dried in a hot air oven at 60 ± 2 °C to reduce the moisture content to the desired level of 5% (wet basis). The samples were withdrawn at regular intervals, and the moisture content was analyzed. The moisture curve obtained for the drying of samples blanched by different methods is shown in Figure 3. The MW-blanched slices dried quickly at the initial stages compared to water- and steam-blanched samples. The time required for drying MW-blanched slices was marginally lower (380 min) compared to the slices blanched by other methods. Steam- and water-blanched samples required nearly 420 and 410 min, respectively, for drying to the desired moisture content. The results showed that water and steam blanching methods did not significantly affect the drying characteristics of potato slices ($p > 0.05$). However, a significant difference in drying time was observed between MW and conventional blanching methods ($p < 0.05$). The reason for the increased drying time in conventional water- and steam-blanched samples can be attributed to starch gelatinization, which in turn makes the cells less permeable to mass transfer.[33] The quicker drying time observed in MW-blanched potato slices is due to the formation of porous structures during MW blanching, which leads to an improved moisture diffusion rate.[7] These results are in agreement with the studies reported on the drying of potato slices[34] and orange-fleshed sweet potato slices.[7]

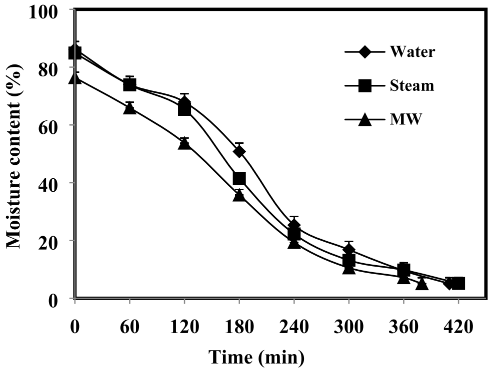

Figure 3. Effect of blanching on the drying of potato slices of 5 mm thickness (MW: microwave).

3.3.4. Rehydration Characteristics. In dried food products, rehydration is considered to be one of the important quality attributes. Processing conditions and composition influence the physical and chemical changes, which in turn affect the rehydration characteristics.[35] This is also an indicator of the product structure. Higher values of rehydration moisture or coefficient indicate a better structure of the product. The moisture content, rehydration ratio, and coefficient values were estimated at the end of rehydration.

Rehydration moisture content in MW-, water-, and steam-blanched slices dried using hot air was 76.95 ± 0.67, 72.53 ± 0.61, and 75.87 ± 0.47%, respectively. The MW-, water-, and steam-blanched slices dried using hot air had rehydration ratios of 3.27, 2.82, and 2.96, respectively. The rehydration coefficients of MW-, water-, and steam-blanched slices dried using hot air were found to be 0.62, 0.51, and 0.53, respectively. The rehydration moisture, ratio, and coefficient values were slightly higher in MW-blanched slices compared to those in slices blanched by other methods. The water-blanched samples gave relatively poor results compared to the MW- and steam-blanched samples. The obtained result showed that there was no significant difference ($p < 0.05$) in rehydration moisture and rehydration ratio between potato slices blanched by different methods, indicating the similarity in the texture of the samples. Potato cubes dehydrated in the cabinet dryer and by microwaves had slower rehydration than samples dehydrated in the belt dryer.[17]

3.3.5. Swelling Power and Starch Solubility. Swelling power indicates the amount of water that a starch molecule can take up, whereas solubility indicates the number of solids that are readily soluble in water. The swelling power and starch solubility were estimated for water-, steam-, and MW-blanched potato samples. These values were compared with those of unprocessed samples. The obtained results indicated that water-blanched (13.51 ± 0.21 g/g) and steam-blanched samples (10.81 ± 0.32 g/g) had marginally higher swelling powers compared to MW-blanched (9.14 ± 0.24 g/g) and unprocessed samples (2.87 ± 0.41 g/g). The starch solubility of MW-blanched samples (11.44 ± 0.34%) was also found to be lower than that of water-blanched (15.72 ± 0.28%) and steam-blanched samples (12.84 ± 0.37%) but higher than that of unprocessed samples (2.5 ± 0.31%). This may be due to the longer processing duration and direct interaction of water with starch molecules present in potato samples during conventional blanching.

3.3.6. Estimation of Drying Rate Constant. A plot of drying rate (dm/dt) versus average moisture content was drawn for the slices blanched by different methods (water, steam, and MW) and dried using hot air (HA) to calculate the drying rate constant (k), as shown in Figure 4. A significant difference in the drying rate constant during HA drying of water-blanched (0.0157 min^{-1}), steam-blanched (0.0206 min^{-1}), and MW-blanched (0.0172 min^{-1}) slices was not observed. The drying rate is almost similar during the initial and final stages of drying for water-, steam-, and MW-blanched samples.

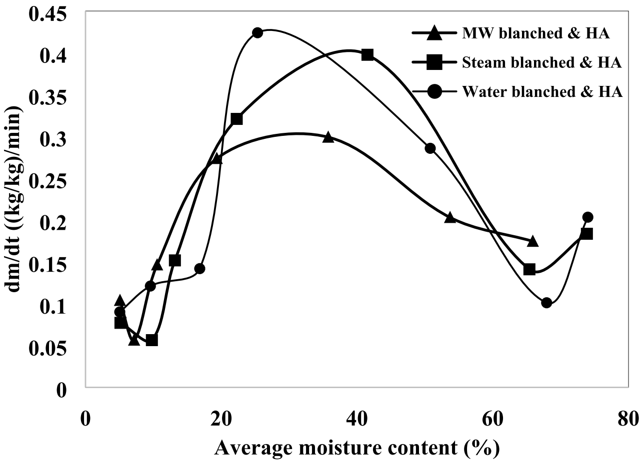

Figure 4. Drying rate curve of potato slices of 5 mm thickness (HA: hot air dried).

3.3.7. Thin Layer Drying Models. The various parameters like *k*, *n*, *a*, *b*, *c*, and *g* were obtained by the nonlinear regression analysis of each model to study the hot air drying characteristics of potato slices (Table 3). The Page, modified

Table 3. Model Constants and Coefficient of Determination of Different Models for Thin Layer Drying of Potato Slices

		method of enzyme inactivation		
model	model constants and coefficients	microwave	water	steam
page	k	1.01×10^{-05}	2.18×10^{-05}	2.65×10^{-05}
	n	2.18	1.98	1.98
	R^2	0.9921	0.9607	0.978
modified page	k	1.29	1.26	1.26
	n	2.18	1.98	1.98
	R^2	0.9921	0.9607	0.978
exponential	k	0.0062	0.0069	0.0082
	R^2	0.9358	0.9155	0.9444
Fick's	k	1.75	1.55	1.5
	n	1.00×10^{-09}	8.00×10^{-10}	9.00×10^{-10}
	R^2	0.9224	0.8942	0.9333
Midilli–Kucuk	k	3.98×10^{-08}	8.85×10^{-09}	2.15×10^{-08}
	n	1.8103	1.9378	1.8688
	a	0.9924	0.9813	0.9951
	b	1.18×10^{-06}	-2.65×10^{-07}	1.39×10^{-06}
	R^2	0.9976	0.9891	0.9929
Hii, Law, and Cloke	a	−0.0098	−11.6602	-7.50×10^{-08}
	k	2.56×10^{-07}	4.23×10^{-06}	3.11×10^{-06}
	n	1.7603	1.3719	1.7537
	c	0.9995	12.6501	1.0095
	g	6.15×10^{-08}	3.94×10^{-06}	6.06×10^{-08}
	R^2	0.9974	0.9888	0.9910

Page, Midilli–Kucuk, and Hii, Law, and Choke models (R^2 = 0.9607–0.9976) performed well compared to Fick's and Exponential models (R^2 = 0.8942–0.9444) in terms of higher coefficient of determination. The drawback of the exponential model is that it tends to overpredict the early stage and underpredict the later stages of drying.[36,37] The Page and modified Page models are the modifications of the exponential model that introduce the exponent (n) to predict the moisture loss well during drying.[38] Kumar et al.[39] also reported that thin layer models, namely, Page and modified Page (R^2 = 0.990–0.995), had a better fit compared to exponential and Fick's (R^2 = 0.767–0.933) for IR-HA drying of onion slices. The Page and modified Page models were reported to fit well for describing oven drying of red bell peppers.[40] Naderinezhad et al.[41] also reported Midilli–Kucuk model was the best-fit model to explain the thin layer drying characteristics of water-blanched potato slices. The Hii, Law, and Choke model fitted well to predict the drying characteristics of hot-air-dried and infrared-dried sweet potato slices.[42]

3.3.8. Mass Transfer during Drying of Potato Slices. The drying curves of water-, steam-, and MW-blanched potato slices (5 mm), as shown in Figure 5, indicated that the moisture content decreased with an increase in drying time. The moisture difference within the product creates a moisture gradient, which in turn facilitates moisture removal. The coefficients of determination (R^2) of water-, steam-, and MW-blanched samples dried using hot air were found to be 0.8942, 0.9333, and 0.9224, respectively. Effective diffusivity (D_{eff}) was calculated using Fick's second law of diffusion (eq 10), and the geometry of the 5 mm potato slice was assumed to be a slab. The effective diffusivity values were obtained from the slope of the semilogarithmic plot of moisture ratio and time (Figure 6). The drying rate during the falling rate period is controlled by moisture diffusion. The effective diffusivity values indicate lower resistance to mass transfer in the drying material. The sample thickness, sample structure (porosity), drying temperature, air velocity, and pressure are the important parameters that can affect the diffusivity of water vapor during the drying

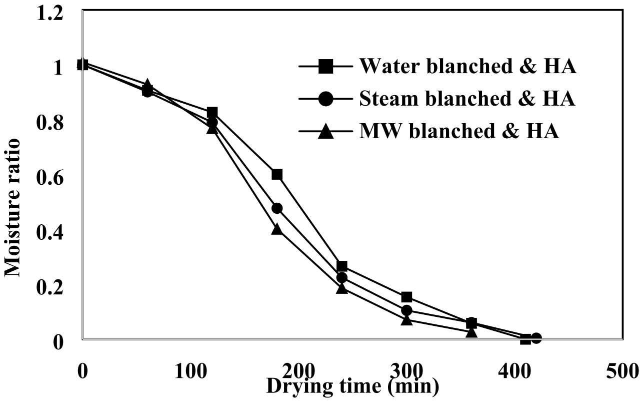

Figure 5. Variation of moisture ratio with respect to drying time for 5 mm potato slices during hot air drying (HA: hot air dried).

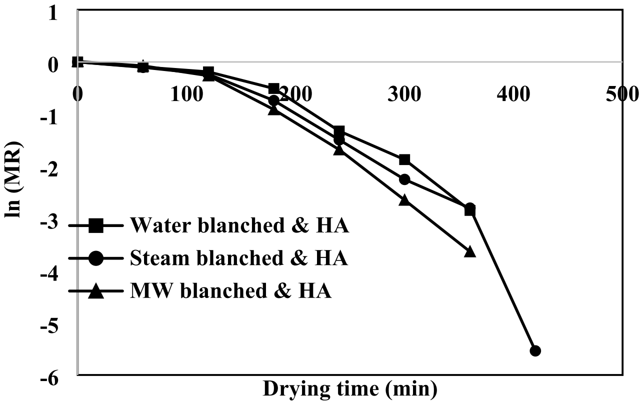

Figure 6. Variation of ln (MR) versus drying time for 5 mm thick potato slices blanched by different methods (HA: hot air dried).

of a product.[40] The MW-blanched (1.14×10^{-9} m^2/s) slices had marginally higher values compared to water-blanched (1.05×10^{-9} m^2/s) and steam-blanched (1.03×10^{-9} m^2/s) slices. The obtained results indicate a higher moisture diffusion in MW-blanched slices than in water-blanched slices. The calculated values are in the range of 10^{-8} to 10^{-12} m^2/s as reported for food materials.[43]

4. CONCLUSIONS

The MW-based dry blanching inactivated the POD enzyme to the desired level in a shorter duration compared with water and steam blanching. A higher amount of ascorbic acid was retained in MW-blanched samples compared to those in steam- and water-blanched samples. Moisture loss observed in MW-blanched samples (~6%) was advantageous during hot air drying, which, in turn, reduced the drying time. The Page, modified Page, Midilli−Kucuk, and Hii, Law, and Choke models predicted the thin layer drying of potato slices better compared with Fick's and Exponential models. The results of the current study showed that MW-based dry blanching can be used as a potential alternative to conventional water and steam blanching to retain a higher amount of water-soluble nutrients like ascorbic acid, in addition to reducing soluble solid loss, processing time, and effluent generation. The effect of other hybrid drying technologies such as infrared, MW-assisted hot air, and vacuum drying of MW-blanched potato slices can be explored in the future to reduce energy consumption and attain superior product quality.

■ ASSOCIATED CONTENT

Data Availability Statement

The data presented in this study are available upon reasonable request from the corresponding author.

■ AUTHOR INFORMATION

Corresponding Author

Jeevitha Gada Chengaiyan − *Department of Biosciences, School of Bio Science and Technology (SBST), Vellore Institute of Technology (VIT), Vellore 632014, India;* orcid.org/0000-0003-4898-8997; Email: jeevitha.gc@vit.ac.in

Authors

Megaswana Guruprasad − *Department of Biotechnology, School of Bio Science and Technology (SBST), Vellore Institute of Technology (VIT), Vellore 632014, India*

Faraz Ahmad − *Department of Biotechnology, School of Bio Science and Technology (SBST), Vellore Institute of Technology (VIT), Vellore 632014, India;* orcid.org/0000-0003-4284-8045

Shafiul Haque − *Research and Scientific Studies Unit, College of Nursing and Allied Health Sciences, Jazan University, Jazan 45142, Saudi Arabia; Centre of Medical and Bio-Allied Health Sciences Research, Ajman University, Ajman P.O. Box 346, United Arab Emirates; Gilbert and Rose-Marie Chagoury School of Medicine, Lebanese American University, Beirut 1102 2801, Lebanon;* orcid.org/0000-0002-2989-121X

Esra Capanoglu − *Department of Food Engineering, Faculty of Chemical and Metallurgical Engineering, Istanbul Technical University, Maslak 34469 Istanbul, Turkey;* orcid.org/0000-0003-0335-9433

Deependra Rajoriya − *Department of Food Technology, Rajiv Gandhi University, Doimukh 791112, India*

Complete contact information is available at: https://pubs.acs.org/10.1021/acsomega.3c09465

Notes

The authors declare no competing financial interest.

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