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Research Article

Drying Kinetics, Effective Moisture Diffusivity, and Activation Energy of Osmotic Pretreated Hot-Air-Dried Paneer Cubes

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Paneer is a heat-acid-coagulated dairy product, and it has a very low shelf life due to its higher moisture content of about more than 50% (w.b). Drying is the best option to reduce moisture, but it takes time and affects the nature of the product. Here, osmotic dehydration (OD) is applied as pretreatment prior to drying to preserve the color and textural changes and reduce the drying time. Commercial NaCl was chosen as osmotic agent. The paneer samples were taken as (2 cm × 2 cm × 2 cm) cubes and pretreated with NaCl, viz., 6%, 12%, 22% *w*/*v*, and surface treatment. The pretreated paneer was dried at 50, 55, and 60°C in a hot-air dryer with constant air velocity of 0.25 m/s. The equilibrium moisture content level was higher in osmotic treated samples compared to the control sample with range between 12.46 and 16.64% (w.b). The osmotic pretreated sample had shortened drying time compared to the control sample. Effective moisture diffusivity and activation energy were calculated, and the osmotic pretreatment impacted positively on it. The drying parameters were fitted with models and found that the Midilli model was ($R^2 > 0.99$) best fit. The osmotic pretreated samples at 50°C drying temperature show ($P \leq 0.01$) better results in color, texture, and sensory profile of dried paneer, while pretreatment is not effective at 55 and 60°C drying temperatures. Except for the carbohydrate content, osmotic pretreated samples retain more fat and protein after the drying process. As a result, it can be concluded that osmotic pretreatment reduces the drying time and retains color, texture, and nutritional characteristics of dried paneer, especially at 50°C drying temperature.

1. Introduction

Milk has been used as a food source in world for a very long period. The diet is significantly impacted by it [1]. India has world's biggest and fastest-growing markets for milk and dairy goods. The average annual increase in milk production was grew by 6.5% [2, 3]. India is the world's largest milk producer, accounting 17% of the global milk production. The milk production went up from 17 million tons in 1950-51 to 187.7 million tons in 2018-2019, and per capita availability of milk was 394 g [4]. Milk is diverted to the creation of domestically sourced milk products with a longer shelf life due to lack of enough refrigeration facilities to keep milk in fresh condition. In India, between 50 and 55% of milk is converted into traditional value-added milk products such puddings made with milk as well as goods that are heat desiccated, cultured, fat-rich, and heat-acid coagulated dairy products [5].

Indian cottage cheese, or paneer, is typically offered for sale in blocks or slices. In India, 7% of the milk is transformed into paneer as a value-added product [6]. Paneer is a heat-treated acid-coagulated dairy product. The protein in paneer has a biological value (BV) that ranges from 80 to 86 [7]. It is particularly perishable in nature due to the high moisture content (55–60%). At refrigeration temperature (4°C), paneer had a shelf life of just 6 days without significantly degrading in quality, but after 3 days, the product's freshness was lost. At room temperature, paneer had a shelf life of not more than one day [6].

There have been several attempts made to extend the shelf life of paneer by using various physical and chemical techniques. They include low-temperature processing (freezing and refrigeration), chemical processing, heat processing, drying, hurdle technology, and packaging [8]. The paneer samples remained stable for 30 days under the chilled condition when added spices like fennel seeds, star anise, and red chilli. The addition of spices enhanced the paneer samples' flavour and taste while also acting as natural preservative and antimicrobial agent [9]. Yadav and Wadehra [10] formulated paneer with addition of mixed spices such as ginger, garlic, cloves, black pepper, and cinnamon. 5% of brine solution and 4% of dry salting were used to enhance shelf life. The shelf life of spiced paneer was extended compared to control paneer which is spoiled on 20 days.

Drying of paneer will surely increase its value and increase its shelf life. But conventional paneer drying techniques are undesirable because they can cause case hardening, inconsistent partial drying, poor rehydration properties, extended drying times, yellow discoloration, and fat separation. And freeze drying is the best option to retain quality, but it requires a high cost for operation. The dehydrated paneer using hot-air drying achieved good shelf life but poor rehydration characteristics [8]. Although drying modifies the physicochemical properties of the dried product, it is still the greatest preservation technique for producing a product that is shelf stable while maintaining its quality traits. Pretreatment before drying is a useful strategy to increase drying kinetics while maintaining the quality of the finished product.

To overcome the limitations, osmotic dehydration (OD) could be used as a pretreatment before drying. OD is an efficient technique for removing water from substrates without causing a phase shift, which decreases the physical, chemical, and biological changes when samples are dried at elevated temperatures. The drying of taikor slices with applying osmotic pretreatment had shorten drying time compared to the unosmosed sample [11]. Reshmi et al. [12] reported that the drying time for anola was decreased from 32 hours to 28 hours when salt concentration increased. The OD-pretreated and untreated kumquat slices dried in vaccum dryer, and Ozkan-karabacak et al. [13] observed that the color retention was higher in the osmotic pretreated samples when compared with the untreated sample.

Additionally, there is no research work carried out on drying for paneer with osmotic pretreatment. The objective of this study is to reduce the drying time of paneer and improve the quality parameters such as color, texture, and sensory profile of dehydrated paneer cubes by applying osmotic pretreatment with different concentrations.

2. Materials and Methods

2.1. Fabrication of Paneer. Paneer was prepared from cow milk using batch pasteurizer (Goma Engineering Pvt Ltd., Mumbai) and manual paneer hooper. Milk was heated up to 90°C without holding by electric pasteurizer and cooled down to 70°C. The coagulation process took place when vinegar at 1% concentration added into the milk slowly with continuous stirring until the clear separation of whey. The coagulation was allowed for further 5 min to settle the curd mass. Muslin cloth was used to drain off the whey from coagulated mix. The obtained curd mass called "chhana"which was pressed by hooper (200 mm × 200 mm × 200 mm). Pressed paneer was immersed in cold water (4°C) to integrate the pressed solid mass particles. After 2 to 3 hours, paneer was sliced into (2 cm × 2 cm × 2 cm) cubes and processed for pretreatment. The prepared paneer was taken as control sample.

2.2. Pretreatment. Osmotic dehydration was taken as pretreatment. Commercial NaCl (salt) was chosen as osmotic agent. Osmotic pretreatment was done in four different concentrations, viz., 6%, 12%, 22% *w*/*v*, and surface (dusting the salt over the paneer cubes on all the sides) treatment. The paneer was soaked in osmotic solution for 12 h at 4°C [12]. The product solution ratio was taken as 1 : 4.

2.2.1. Estimation of Weight Reduction, Water Loss, and Solute Gain. Both water loss and solute gain occurred concurrently during osmotic dehydration. Water loss leads to a drop in initial mass, while solute permeability leads to an increase. Therefore, water loss (WL) is the sum of weight reduction (WR) and solute gain (SG). WR, WL, and SG were determined using Equations (1), (2), and (3) as reported by [14].

$$\text{WR in g} = W_i - W_t, \tag{1}$$

$$\text{WL/100gof sample } \frac{(W_i - W_t) + (S_i - S_t)}{W_i} \times 100, \tag{2}$$

$$\text{SG/100gof sample} = \frac{S_i - S_t}{W_i} \times 100, \tag{3}$$

where W_i denotes the initial weight of the sample in g. W_t denotes the weight of the sample after OD at a time "*t*" in g. S_i denotes the initial weight of solids (dry matter) in the sample in g, and S_t denotes the weight of solids (dry matter) of the sample after OD for time "*t*" in g.

2.3. Drying Kinetics

2.3.1. Drying Procedure. The control and pretreated paneer cubes were placed in tray (600 × 600 × 20 mm) and dried in different temperature, viz., 50, 55, and 60°C at constant

Table 1: Drying models considered for modeling the collected moisture ratio.

Model	Model equation	References
Page	$MR = \exp\left(-at^{b}\right)$	[13]
Logarithmic	$MR = a\ \exp\ (-bt) + c$	[17]
Wang and Singh	$MR = 1 + at + bt^{2}$	[19]
Midilli	$MR = a\ \exp\left(-bt^{d}\right) + ct$	[20]
term exponential-Two	$MR = a\ \exp\ (-bt) + (1 - a)\ \exp\ (-cat)$	[21]
Henderson and Pabis	$MR = a\ \exp\ (-bt)$	[15]

Table 2: WL, SG, and WR values (mean ± SD) observed during different concentration of osmotic pretreatment on paneer cubes.

Sample	Water loss (wt.%)	Solute gain (wt.%)	Weight reduction (wt.%)
6% OD	-18.42 ± 0.13^{a}	1.19 ± 0.04^{b}	-19.61 ± 0.08^{a}
12% OD	-11.85 ± 0.05^{b}	3.49 ± 0.02^{c}	-15.34 ± 0.03^{b}
22% OD	2.99 ± 0.08^{c}	8.78 ± 0.06^{d}	-5.79 ± 0.02^{c}
Surface OD	8.76 ± 0.07^{d}	0.55 ± 0.03^{a}	8.21 ± 0.04^{d}
F value	40305.787^{**}	11583.550^{**}	44313.482^{**}

Average of three trials. **Highly significant ($P \leq 0.01$) at intervals. Superscripts with same letter indicate that the treatments are on par.

air velocity of 0.25 m/s in tray dryer (Everflow Scientific Instruments, Chennai). The weight reduction was measured in one-hour interval by using digital weighing balance (Shimadzu Pvt Ltd., Chennai) with readability precision of 0.0001 g (0.1 mg). The determinations were replicated multiple times, and the average values were used to evaluate moisture content, drying rate, drying time, and moisture ratio.

2.3.2. Assessment of Moisture Content. The drying rate for paneer was determined using Equation (4) as reported by [15].

$$MC, \% = \frac{W_w}{W_d} \times 100, \tag{4}$$

where MC signifies the moisture content in % (w.b.), W_w signifies the weight of water evaporated to make the paneer-dry condition in *g*, and W_d signifies the initial weight of paneer in g.

2.3.3. Assessment of Drying Rate. The drying rate for paneer was determined using Equation (5) as mentioned by [15].

$$K = \frac{W_w}{t}, \tag{5}$$

where K represents the drying rate in g/h, W_w represents the quantity of moisture evaporated in g; t represents the time taken for drying in h.

2.3.4. Assessment of Moisture Ratio. The moisture ratio for paneer was found using equation (6) as given by [16].

$$MR = \frac{M - M_e}{M_0 - M_e}, \tag{6}$$

Figure 1: Drying of paneer on trays in tray dryer.

where MR denotes the moisture ratio in dimensionless value, M denotes the moisture content at any time t in % w.b, M_0 denotes the initial moisture content in % (w.b.), and M_e denotes the equilibrium moisture content in % (w.b.).

2.3.5. Estimation of Effective Moisture Diffusivity. Fick's second law proposed the equation to find out the effective moisture diffusivity. Therefore, the moisture diffusivity of cube sample was determined using Equation (7) as suggested by [17].

$$MR = \left[\frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n-1)2}\exp\left(-\frac{(2n-1)2\,\pi 2\,D\,t}{L2}\right)\right]^{3}, \tag{7}$$

where MR represents the moisture ratio (unitless), D represents the effective moisture diffusivity in m^2s^{-1}, t represents the drying time in s, L represents the cube length in m, and n represents the list of positive integers.

For long drying period, first term of Equation (7) is considered to find out the effective moisture diffusivity (D), and

Table 3: Equilibrium moisture content and drying time of dried paneer cubes.

Sample	Equilibrium moisture content (% w.b.)			Drying time (h)		
	At 50°C	At 55°C	At 60°C	At 50°C	At 55°C	At 60°C
Control	15.26	14.65	12.46	58	57	51
6% OD	15.71	15.31	13.63	56	55	49
12% OD	16.47	15.37	12.53	55	54	48
22% OD	16.54	15.84	15.16	53	52	48
Surface OD	16.64	16.59	15.89	52	52	50

the rest is negligible. Hence, the slope (k_0) was obtained from the linear line in plotting ln (MR) against time, t as mentioned in Equation (8). The effective moisture diffusivity is calculated using Equation (9) [16, 17].

$$MR = \left(\frac{8}{\pi^2}\right)^3 \exp\left(-\frac{\pi 2\, D\, t}{L2}\right)^3, \quad (8)$$

$$k_0 = -\frac{3\pi 2D}{L2}. \quad (9)$$

2.3.6. Estimation of Activation Energy. In general, an Arrhenius type equation is used to express the moisture diffusivity of food components at various temperatures. From Equation (10), the slope (k_1) of straight line is found by plotting ln (D) against 1/T. The activation energy (E_a) is determined using Equation (11) [16, 18].

$$D = D_0 \exp\left(-\frac{E_a}{RT}\right) \quad (10)$$

$$K_1 = \frac{E_a}{R}, \quad (11)$$

where D denotes the effective moisture diffusivity in m^2s^{-1}, D_0 denotes the preexponential factor in m^2/s, E_a denotes the activation energy in KJ/mol, R denotes the universal gas constant (8.314 J/mol.K), and T denotes the drying temperature, respectively.

2.4. Empirical Models. The experimental data of moisture ratio were compared to six well-proven models such as Page, logarithmic, Wang and Singh, Midilli, two-term exponential, and Henderson and Pabis. In order to find the best-fitting model for the paneer drying process, the regression value (R^2) and model constants (a, b, and c) were evaluated with time (t) in the model equations as represented in Table 1. The Curve Expert software was used to fit the data.

MR- Moisture ratio; a, b, c- model constants, t- time.

2.5. Determination of Color. The color parameters (L^*, a^*, and b^*) were measured using a Hunter Lab colorimeter. The Xenon flash lamp was the light source. The illuminant used for this study was D65 and 10° observer [22]. The whiteness index of paneer was evaluated using equation (12) as mentioned by [23].

$$\text{Whiteness Index (WI)} = 100 - \sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}}, \quad (12)$$

where L^* signifies the darkness to lightness, a^* signifies the greenness to redness, and b^* signifies the blueness to yellowness.

2.6. Texture Profile Analysis. The texture profile analysis of paneer was done by a texture analyzer (Model: TA.XT Plus, Make: Stable Micro Systems, Surrey). This equipment was carried out with following test conditions such as 50 kg load capacity, 10 mm distance, 5 mm/sec test speed, and 5 g trigger force. The compression palate (P/75) probe was used to determine the textural parameters.

2.7. Proximate Analysis. The proximate analysis of paneer samples was analyzed by conventional methods of AOAC [24]. The fat, protein, and moisture contents were expressed in %. Protein was estimated by the Kjeldahl method, and the fat was quantified by the Soxhlet apparatus. The ash and carbohydrate contents were determined by the AOAC procedures.

2.8. Sensory Evaluation. Dehydrated paneer samples were assessed by a well-trained sensory panelist from the College of Food and Dairy Technology, Chennai, Tamil Nadu, in the age group of 25–58. All sensory panel members were provided with an appropriate score card on which product sensory attributes such as color, appearance, flavour, texture, and overall acceptability of the product were scored on a nine-point hedonic scale [25].

2.9. Statistical Analysis. The analysis was conducted in three replications. All the analyses were performed using IBM SPSS® 20.0 for Windows® software as per the standard procedure of Snedecor and Cochran [26]. The level of difference was calculated by the Duncan multiple comparison test ($P \leq 0.05$). The difference was considered highly significant when ($P \leq 0.01$), significant when ($0.01 > p \leq 0.05$) and not significant when ($p > 0.05$). Results were represented as the mean ± standard deviation (SD).

3. Results and Discussion

3.1. Osmotic Pretreatment. Water loss (WL), solute gain (SG), and weight reduction (WR) were observed during osmotic pretreatment. Table 2 shows the WL, SG, and WR in different osmotic pretreatment. The WL was noted higher at surface OD-treated paneer sample and lower in 6% OD-treated

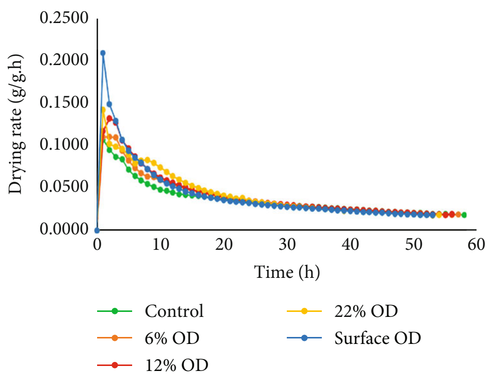

Figure 2: Drying rate characteristics of paneer cubes dried at 50°C.

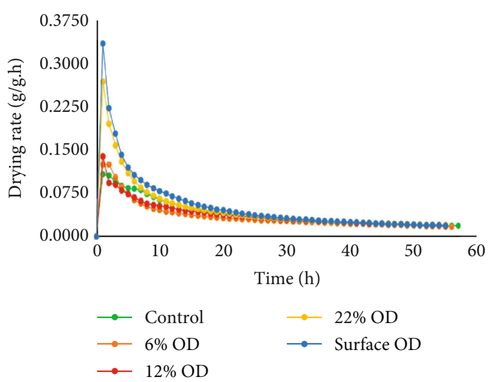

Figure 3: Drying rate characteristics of paneer cubes dried at 55°C.

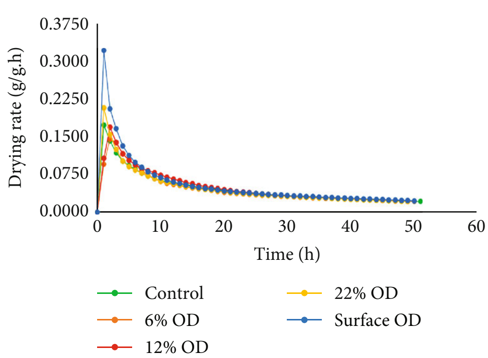

Figure 4: Drying rate characteristics of paneer cubes dried at 60°C.

sample with the values of 8.76 ± 0.07% and −18.42 ± 0.13%, respectively. The SG (%) was gradually increased from 1.19 ± 0.04 to 8.78 ± 0.06 while increasing osmotic concentration from 6% to 22%, respectively. The WL was observed negatively in 6% and 12% OD-treated samples due to paneer absorbed water during osmotic pretreatment. The paneer primarily consists of a complex arrangements of casein micelles that enclose various milk components with close-knit texture, and casein has a water-holding capacity [27]. So, the paneer absorbs more moisture in lower osmotic level through weakening the knit texture, and it was impacted negatively in WL. A surface salt-treated sample recorded lowest SG among the samples with average value of 0.55 ± 0.03%. The weight

Table 4: Effect of temperature and OD on moisture diffusivity (D).

Temperature	Sample	Slope (k_0)	Average value of moisture diffusivity (m^2/s)
50°C	Control	0.0000164	2.15×10^{-8}
	6% OD	0.0000183	2.40×10^{-8}
	12% OD	0.0000181	2.38×10^{-8}
	22% OD	0.0000177	2.32×10^{-8}
	Surface OD	0.0000180	2.36×10^{-8}
55°C	Control	0.0000167	2.19×10^{-8}
	6% OD	0.0000204	2.68×10^{-8}
	12% OD	0.0000179	2.35×10^{-8}
	22% OD	0.0000189	2.48×10^{-8}
	Surface OD	0.0000192	2.52×10^{-8}
60°C	Control	0.0000285	3.75×10^{-8}
	6% OD	0.0000280	3.68×10^{-8}
	12% OD	0.0000293	3.85×10^{-8}
	22% OD	0.0000286	3.76×10^{-8}
	Surface OD	0.0000275	3.61×10^{-8}

reduction was seen in the surface OD-treated sample, and mass of other treated samples were increased due to its solute gain and absorption of water. The WL and SG were ($P \le 0.01$) proportional with the NaCl concentration of the osmotic solution, and the penetration rate of salt is higher compared to other osmotic agents due to its low molecular nature. The results were found in agreement with [28] who reported that water loss, solute gain, and weight reduction were increased when the osmotic concentration of solution increases. This phenomenon is due to higher moisture diffusion which takes place when it has more solutes to absorb.

3.2. Drying Kinetics

3.2.1. Effect of Osmotic Pretreatment on Drying. The control and OD-treated samples were placed in trays and dried at respective temperature, as shown in Figure 1. The initial moisture content of the paneer sample was 55.06% (w.b.). The drying time and equilibrium moisture content (EMC) of paneer samples dried at 50, 55, and 60°C and are presented in Table 3.

Figures 2–4 visualize the drying rate characteristics of paneer cubes at different temperatures. The EMC of paneer samples dried at 50°C were ranges between 15.26 and 16.64% (w.b.), and the range of drying time was between 52 and 58 h. The drying rate was higher in the surface OD-treated sample with a value of 0.2080 g/g.h. The samples dried at 55°C show EMC ranges from 14.65 to 16.59% (w.b.), and the drying time was between 52 and 57 h. The higher drying rate lies with surface OD-treated sample with value of 0.3352 g/g.h. The EMC of samples dried at 60°C were ranges between 12.46 and 15.89% (w.b.), and the range of drying time was between 48 and 51 h. The highest drying

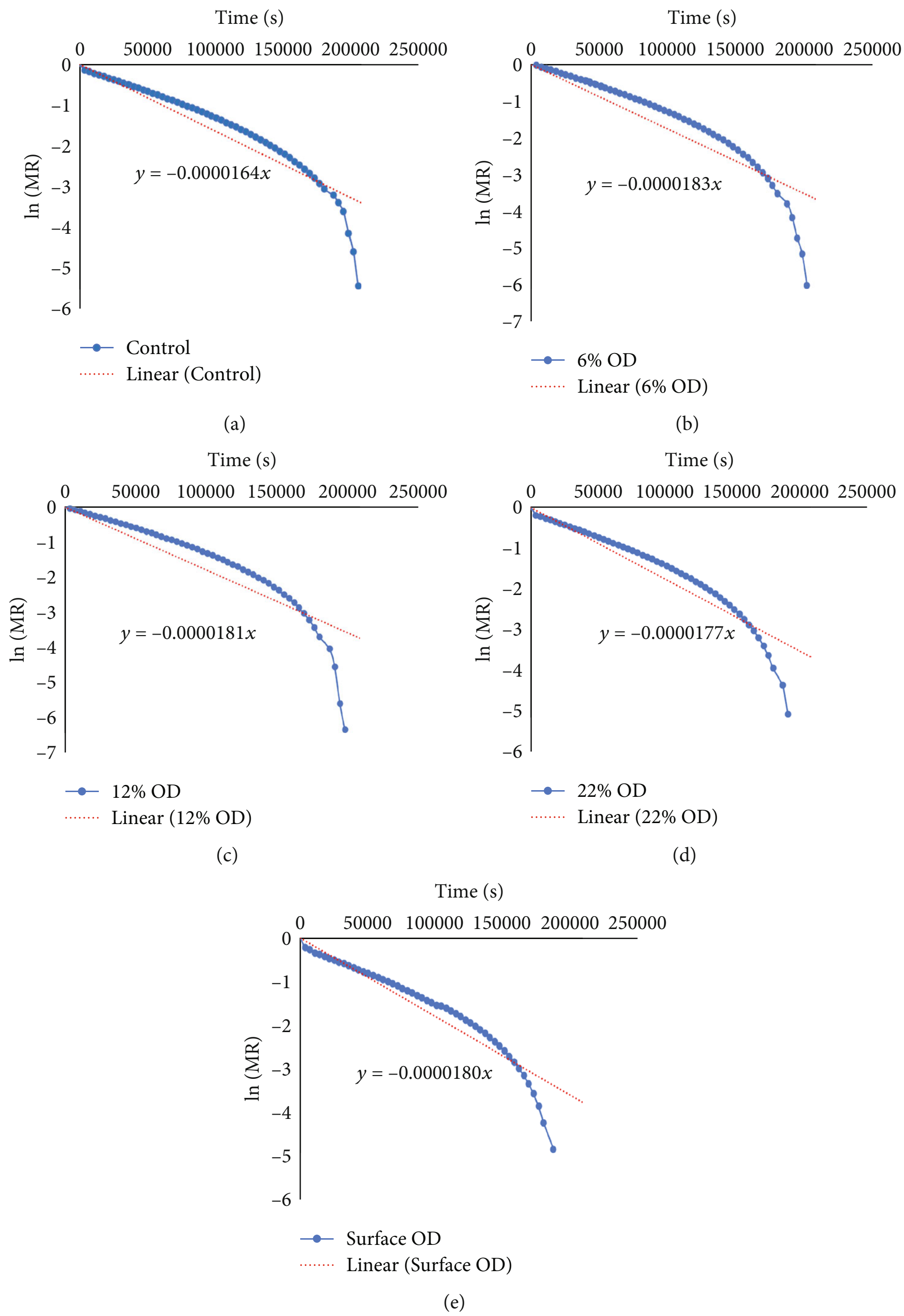

Figure 5: (a) ln (MR) versus time for tray drying at 50°C for control sample. (b) ln (MR) versus time for tray drying at 50°C for 6% OD sample. (c) ln (MR) versus time for tray drying at 50°C for 12% OD sample. (d) ln (MR) versus time for tray drying at 50°C for 22% OD sample. (e) ln (MR) versus time for tray drying at 50°C forSurface OD sample.

rate was higher in surface-treated sample with the value of 0.3213 g/g.h. The surface OD treatment reduces moisture content with low-solute gain compared to other concentrations. The solutes present in surface of the product were due to direct contact with the salt. The moisture was quickly reduced at the initial phase of drying because of salt action, it may be reason to drying rate was observed higher in the surface OD sample. The drying rate of surface OD-treated sample dominates over other samples in all temperature at initial phase of drying phase which is validate by plotting lines in Figures 2–4.

The drying time and EMC of paneer were reduced in the drying temperature 60°C followed by 55°C and 50°C temperatures. In higher air-drying temperature, the gradient potential was high which leads to reduction in drying time. These results correlated with several authors [29] who observed that the drying time for quinces and [30] for tomato pomace in different. The OD-treated samples had shorten drying

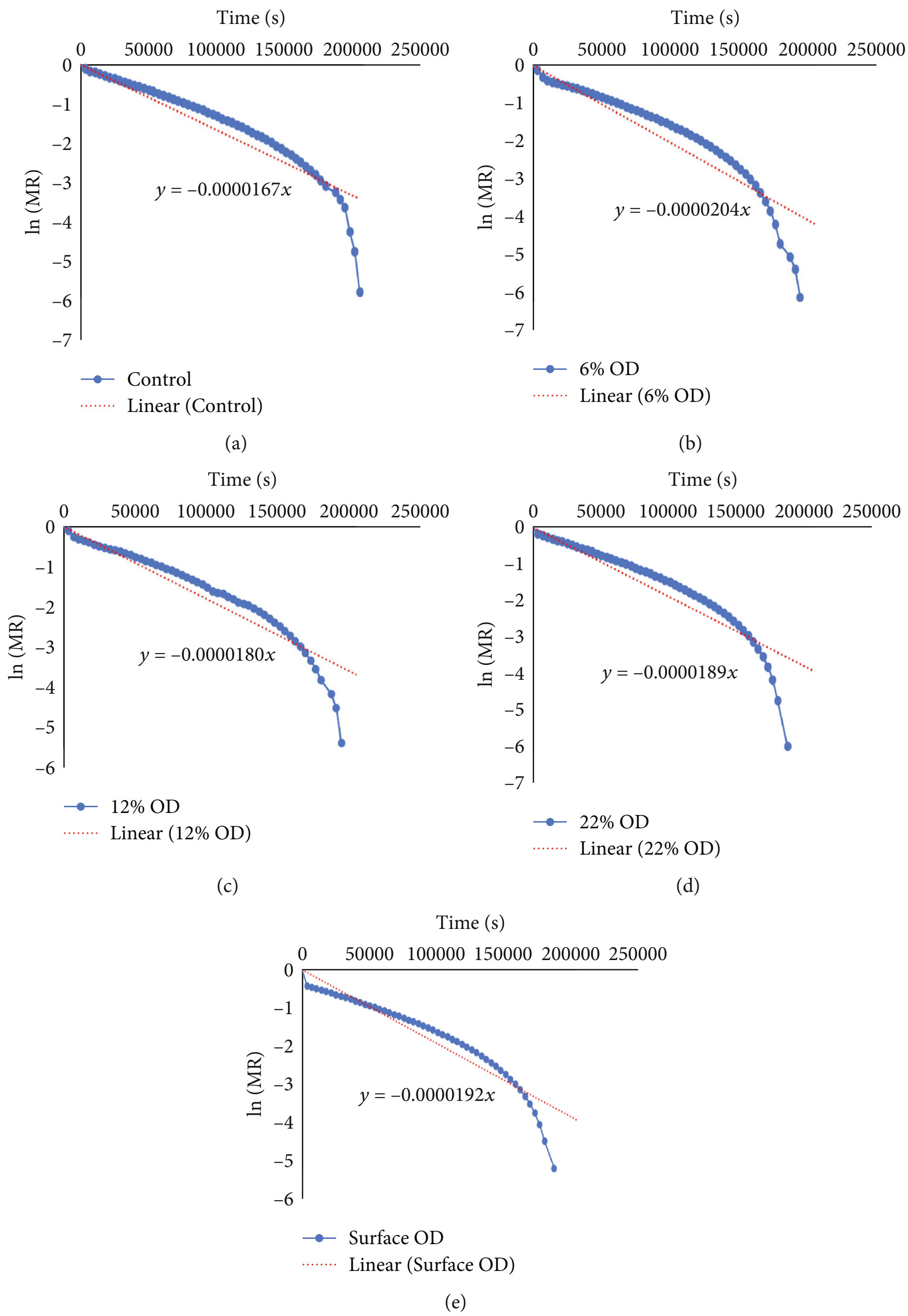

FIGURE 6: (a) ln (MR) versus time for tray drying at 55°C for control sample. (b) ln (MR) versus time for tray drying at 55°C for6% OD sample. (c) ln (MR) versus time for tray drying at 55°C for 12% OD sample. (d) ln (MR) versus time for tray drying at 55°C for 22% OD sample. (e) ln (MR) versus time for tray drying at 55°C for surface OD sample.

time compared to the control sample due to its faster drying rate in the OD-treated sample. The OD-pretreated sample shows energy saving by reducing its processing time [31, 32].

The EMC of OD-treated samples was higher compared to the control sample in all the drying temperature. The EMC was higher when increased the osmotic concentration of solution in pretreatment. The moisture content was higher at a final phase of drying as salt uptake influences the water sorption behavior of paneer. In addition, the researchers reported that solid deposition and internal mass resistance of NaCl lead to higher moisture at the end. Similar findings were noted by [12, 33].

3.2.2. Effective Moisture Diffusivity. The effective diffusivity of paneer sample on different temperatures is presented in Table 4. The moisture diffusivity was calculated by Equation (9) and depicted in Figures 5–7. The moisture diffusivity of paneer samples dried at 50°C was ranged between 2.15×10^{-8}

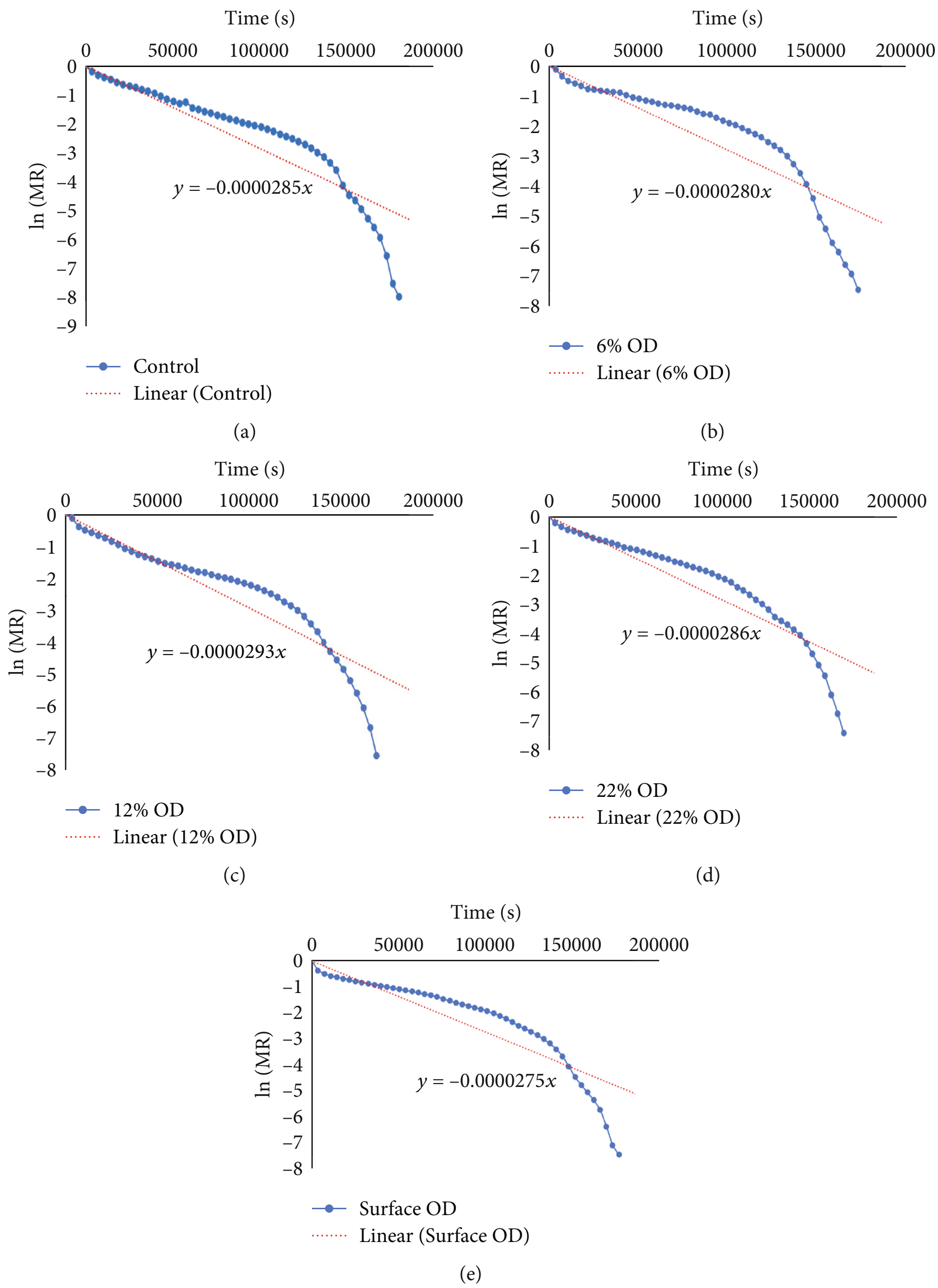

Figure 7: (a) ln (MR) versus time for tray drying at 60°C for control sample. (b) ln (MR) versus time for tray drying at 60°C for 6% OD sample. (c) ln (MR) versus time for tray drying at 60°C for12% OD sample. (d) ln (MR) versus time for tray drying at 60°C for 22% OD sample. (e) ln (MR) versus time for tray drying at 60°C for surface OD sample.

and 2.40×10^{-8} m^2/s. For samples dried at 55°C were ranged between 2.19×10^{-8} and 2.68×10^{-8} m^2/s, and for 60°C were ranged between 3.61×10^{-8} and 3.85×10^{-8} m^2/s. These values were under the normal range of 10^{-8} to 10^{-12} m^2/s for drying of food substances [34].

The moisture diffusivity varies with the drying temperature and moisture content of paneer [35]. The increase in drying temperature accelerated the surface evaporation and enhanced internal moisture movement. As a result, higher diffusivity range was seen in samples dried at higher temperature. Similar observation was reported by [16, 36]. The observed moisture diffusivity values of paneer samples were relatable to [37] who dried the tofu and observed diffusivity value in range of 10^{-8} m^2/s. The OD-treated samples had more diffusivity compared to the control sample in all the drying temperature, and this might be due to NaCl accelerates the internal moisture diffusion during drying process. Similar phenomena were reported by [32] for tomato and [38] for pitahaya. The D value of samples dried at 50°C and 55°C was almost reduced when the osmotic concentration increased in pretreatment,

Table 5: Effect of OD pretreatment on activation energy.

Sample	Equation	Slope (k_1)	Activation energy (KJ/mol)
Control	$y = -5526.2x - 0.6062$	5526	45.94
6% OD	$y = -4253x - 4.3921$	4253	35.36
12% OD	$y = -4816.8x - 2.7049$	4816	40.04
22% OD	$y = -4798.4x - 2.7582$	4798	39.89
Surface OD	$y = -4238.1x - 4.4693$	4238	35.24

and these might be due to increasing solid content [39]. These results were relatable with other food materials: [36] for pepper, [39] for tomato, and [40] for apricot.

3.2.3. Activation Energy. Table 5 illustrates the activation energy required for the control and osmotic dehydrated samples. The slope of ln(D) plotted against 1/T was used to compute the activation energy, which was visualized in Figure 8.

The activation energy of the control paneer sample was 45.94 KJ/mol, and the OD-treated samples were ranges from 35.24 to 40.04 KJ/mol. Generally, the activation energy for food materials were range between 12 and 110 KJ/mol [40]. Similar ranges of activation energy value were observed by [18, 41]. Figure 8 clearly shows the control sample had a lowest diffusivity variable in different temperatures, and the OD-treated samples were ahead. The activation energy for control sample was higher than the OD-treated samples. This might be due to osmotic pretreatment leads to diffuse the moisture before the drying itself. Additionally, the moisture diffusivity was higher in OD-treated sample. Therefore, it needs only lower energy required to initiate the drying process for osmotic treated samples. Similar correlations were reported by [18, 37].

3.2.4. Modeling of Drying Kinetics. There are six thin layer models, such as page, logarithmic, Wang and Singh, Midilli, two-term exponential, and Handerson and Pabis that were used to determine the statistical parameters of the drying kinetics of paneer. The moisture ratio values were recorded during the drying period of each sample at different temperatures and tested with the above-mentioned models. The drying constants, R^2, SEE, and RMSE values of each empirical model on drying kinetics of paneer at 50, 55 and 60°C were calculated and represented on Tables 6–8. The best-fit model was chosen for drying kinetics of paneer on basis of highest R^2 value and lowest RMSE value.

Out of these models, the R^2 value was obtained above >0.95 except for Wang and Singh model. From Tables 6–8, it was observed that the Midilli model had maximal R^2 value > 0.99 and minimal RMSE value. Hence, Midilli model was chosen as the best-fit model for all the samples dried at 50, 55 and 60°C. The observed result was relatable to drying kinetics of other food products in tray dryer. [42] who reported that the Midilli model was the best-fit model among other models for drying kinetics of banana and same as [43] for kiwifruit slices in tray dryer.

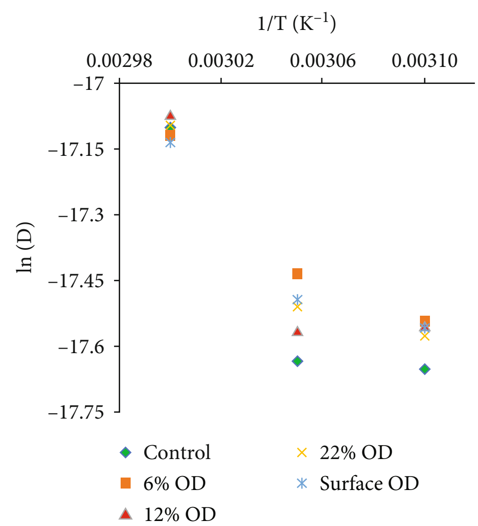

Figure 8: ln (D) versus 1/T at different temperature.

3.2.5. Effect of Osmotic Pretreatment on Color. The color is the most significant parameter in the physical appearance of the paneer. The L^*, a^*, and b^* values of dehydrated paneer samples are shown in Table 9. The L^*, a^*, and b^* values of the fresh paneer sample were 87.18 ± 0.20, -0.129 ± 0.01, and 15.69 ± 0.11, respectively. The drying of paneer in 50, 55, and 60°C temperatures had statistically high significant difference ($P \leq 0.01$) in L^*, a^*, and b^* values of paneer samples. The lowest value was noted in the control paneer sample which was dried at 60°C with mean value of 69.75 ± 0.67, 5.33 ± 0.14, and 29.86 ± 0.31 for L^*, a^*, and b^* values.

The OD-treated samples had more color retention, and NaCl shows a positive impact on color of dried paneer. The NaCl preserves color by reducing moisture availability for physicochemical and enzymatic reactions during the drying process. The observed phenomena can relate with many authors, that the L^* value was higher in osmotic pretreated samples when compared with the untreated sample by [43] in kiwifruit slices, [30] in pomace, and [33] in shombo and bava cultivars. The lower a^* value was observed in osmotic treated samples compared to the control sample and found in agreement with [33]. Among the dried paneer samples, surface treatment and 22% of OD concentration were superior in each temperature. The water binding ability is more in higher concentration of NaCl, so it preserves color more than lower concentration.

Table 6: Values of coefficients and statistical parameters for tray drying of paneer at 50°C.

Sample	Models	Parameter values	R^2 value	SSE	RMSE
Control	Page	$a = 0.052$; $b = 1.003$	0.9857	0.0583	0.0319
	Logarithmic	$a = 1.047$; $b = 0.036$; $c = -0.130$	0.9977	0.0094	0.013
	Wang and Singh	$a = -0.038$; $b = 0.0003$	0.97	0.1225	0.0463
	Midilli	$a = 0.962$; $b = 0.067$; $c = -0.002$; $d = 0.835$	0.9987	0.0051	0.0096
	Two-term exponential	$a = 0.047$; $b = 24.24$; $c = 1.062$	0.9881	0.0483	0.0293
	Henderson and Pabis	$a = 0.961$; $b = 0.050$	0.9887	0.0502	0.0296
6% OD	Page	$a = 0.070$; $b = 0.922$	0.9794	0.0725	0.0366
	Logarithmic	$a = 1.008$; $b = 0.036$; $c = -0.126$	0.9947	0.0187	0.0187
	Wang and Singh	$a = -0.040$; $b = 0.0004$	0.9468	0.1877	0.0589
	Midilli	$a = 0.966$; $b = 0.101$; $c = -0.003$; $d = 0.689$	0.998	0.0071	0.0117
	Two-term exponential	$a = 0.080$; $b = 14.91$; $c = 0.631$	0.9877	0.0432	0.0285
	Henderson and Pabis	$a = 0.921$; $b = 0.051$	0.9859	0.0497	0.0303
12% OD	Page	$a = 0.019$; $b = 1.262$	0.9963	0.0180	0.0182
	Logarithmic	$a = 1.225$; $b = 0.033$; $c = -0.199$	0.9998	0.0008	0.0039
	Wang and Singh	$a = -0.033$; $b = 0.0002$	0.9988	0.0057	0.0102
	Midilli	$a = 1.014$; $b = 0.031$; $c = -0.001$; $d = 1.069$	0.9999	0.0004	0.0028
	Two-term exponential	$a = 0.187$; $b = 0.046$; $c = 0.245$	0.9788	0.1039	0.0442
	Henderson and Pabis	$a = 1.081$; $b = 0.049$	0.9865	0.0661	0.0350
22% OD	Page	$a = 0.060$; $b = 0.981$	0.9827	0.0620	0.0348
	Logarithmic	$a = 1.047$; $b = 0.038$; $c = -0.142$	0.9966	0.0121	0.0156
	Wang and Singh	$a = -0.041$; $b = 0.0004$	0.9646	0.127	0.0499
	Midilli	$a = 0.965$; $b = 0.083$; $c = -0.003$; $d = 0.773$	0.9984	0.0057	0.0108
	Two-term exponential	$a = 0.062$; $b = 15.97$; $c = 0.870$	0.9869	0.0468	0.0306
	Henderson and Pabis	$a = 0.95$; $b = 0.054$	0.9861	0.0499	0.0313
Surface OD	Page	$a = 0.073$; $b = 0.922$	0.9739	0.0873	0.0413
	Logarithmic	$a = 1.027$; $b = 0.036$; $c = -0.156$	0.9934	0.0220	0.0209
	Wang and Singh	$a = -0.042$; $b = 0.0004$	0.9431	0.1901	0.0610
	Midilli	$a = 0.963$; $b = 0.112$; $c = -0.004$; $d = 0.647$	0.9969	0.0105	0.0146
	Two-term exponential	a =0.072; b =15.95; c =0.747	0.9832	0.0562	0.0335
	Henderson and Pabis	$a = 0.916$; $b = 0.053$	0.9818	0.0607	0.0345

WI value was calculated by mean values of L^*, a^*, and b^* values of sample. The WI for the fresh paneer sample was 79.74. The WI for paneer samples dried at 50°C was ranged between 62.23 and 77.03. The WI for paneer sample dried at 55°C were ranged between 59.75 and 67.10, and for paneer samples dried at 60°C were ranged between 57.16 and 59.35.The WI of fresh paneer sample was almost similar with the literature [23]. The WI was affected in the control sample due to its physicochemical changes happen at drying. The lowest range was observed in 60°C which showed yellowish brown color appearance, and the temperature 50°C and 55°C had minimal color changes. The specific gravity of milk fat is lower, so it predominates the surface of the paneer during drying. So, it complicates the color changes. These changes can validate by Figure 9 which visualizes the three rows of dried paneer samples where the first row illustrates the samples dried at 50°C followed by 55 and 60°C in next two rows. The WI of paneer samples dried at 50°C was commensurable with the WI of fresh paneer sample. The researchers Mishra et al. [44] were observed this similar type of changes in paneer at different temperatures.

3.2.6. Effect of Osmotic Pretreatment on Sensory. It was observed from Table 10 that the sensory scores of color, flavour, body and texture, and overall acceptability of paneer samples resulted in a significant difference when dried at different temperatures. In the sensory scores of color and appearance, the T_5 sample was highly scored as “like very

Table 7: Values of coefficients and statistical parameters for tray drying of paneer at 55°C.

Sample	Models	Parameter values	R^2 value	SSE	RMSE
Control	Page	$a = 0.145$; $b = 0.78$	0.9883	0.0370	0.0257
	Logarithmic	$a = 0.885$; $b = 0.075$; $c = 0.021$	0.9773	0.0721	0.0362
	Wang and Singh	$a = -0.048$; $b = 0.0005$	0.8147	0.5878	0.1025
	Midilli	$a = 1.037$; $b = 0.193$; $c = -0.001$; $d = 0.655$	0.9933	0.0211	0.0198
	Two-term exponential	$a = 0.317$; $b = 0.302$; $c = 0.172$	0.9915	0.0269	0.0221
	Henderson and Pabis	$a = 0.888$; $b = 0.068$	0.9761	0.0759	0.0368
6% OD	Page	$a = 0.094$; $b = 0.881$	0.9696	0.1056	0.0442
	Logarithmic	$a = 0.959$; $b = 0.044$; $c = -0.100$	0.9867	0.0462	0.0295
	Wang and Singh	$a = -0.044$; $b = 0.0005$	0.9178	0.286	0.0727
	Midilli	$a = 0.977$; $b = 0.141$; $c = -0.003$; $d = 0.643$	0.9922	0.0272	0.0229
	Two-term exponential	$a = 0.134$; $b = 1.594$; $c = 0.425$	0.981	0.0661	0.0353
	Henderson and Pabis	$a = 0.899$; $b = 0.059$	0.9769	0.0803	0.0385
12% OD	Page	$a = 0.087$; $b = 0.919$	0.9929	0.0251	0.0218
	Logarithmic	$a = 0.960$; $b = 0.058$; $c = -0.033$	0.9956	0.0156	0.0173
	Wang and Singh	$a = -0.046$; $b = 0.0005$	0.938	0.2213	0.0646
	Midilli	$a = 0.999$; $b = 0.113$; $c = -0.001$; $d = 0.783$	0.9993	0.0024	0.0069
	Two-term exponential	$a = 0.915$; $b = 0.062$; $c = 1.093$	0.9954	0.0164	0.0178
	Henderson and Pabis	$a = 0.944$; $b = 0.064$	0.9939	0.0216	0.0202
22% OD	Page	$a = 0.067$; $b = 0.949$	0.9806	0.0668	0.0362
	Logarithmic	$a = 1.029$; $b = 0.038$; $c = -0.137$	0.9955	0.0491	0.0316
	Wang and Singh	$a = -0.041$; $b = 0.0004$	0.9559	0.152	0.0545
	Midilli	$a = 0.901$; $b = -0.005$; $c = -0.040$; $d = 1.268$	0.9957	0.0153	0.0175
	Two-term exponential	$a = 0.081$; $b = 24.45$; $c = 0.646$	0.9875	0.0431	0.0293
	Henderson and Pabis	$a = 0.934$; $b = 0.053$	0.9859	0.0485	0.0308
Surface OD	Page	$a = 0.182$; $b = 0.672$	0.9482	0.1259	0.0496
	Logarithmic	$a = 0.837$; $b = 0.040$; $c = -0.083$	0.9674	0.0792	0.0398
	Wang and Singh	$a = -0.047$; $b = 0.0005$	0.7535	0.5989	0.1084
	Midilli	$a = 0.992$; $b = 0.325$; $c = -0.006$; $d = 0.310$	0.9956	0.0107	0.0148
	Two-term exponential	$a = 0.267$; $b = 16.82$; $c = 0.185$	0.9862	0.0334	0.0258
	Henderson and Pabis	$a = 0.782$; $b = 0.053$	0.9622	0.0917	0.0424

much" in a 9-point hedonic scale with mean value of 8.20 ± 0.17, and T_{11} sample was scored the lowest mean value of 4.13 ± 0.09 (poor rating). Comparing the sensory scores of flavour, T_5 sample was highly scored with mean value of 8.00 ± 0.19, and T_{11} sample was scored lowest with mean value of 4.93 ± 0.40 followed by T_6, T_8, and T_{12} sample with mean values of 5.33 ± 0.30, 5.33 ± 0.18, and 5.33 ± 0.43. The OD-treated samples had significant impact on sensory evaluation which preserves the natural color, body, and texture of the paneer. The color and appearance impact the major role in sensory evaluation. The drying temperature impacted highly significant difference ($P \leq 0.01$) in sensory scores of color and flavour. The color, appearance, and flavour score were rated poorly in 55°C and 60°C temperature dried samples. This might be due to fat separation and milk fat significantly impact on organoleptic quality of paneer [25, 44].

Among the sensory scores of body and texture, T_5 sample was highly scored with the mean value of 8.07 ± 0.59, and T_7 sample was scored low with the mean value of 5.20 ± 0.31. Figure 9 resembles the body and texture of samples dried at 60°C was rough, while the texture of samples dried at 50°C was plain without the case hardening. Usually, the physicochemical and enzymatic reactions effect was more in higher drying temperature. Statistically, the dried sample shows ($P \leq 0.01$) high significant difference among the body and texture scores. By comparing the overall acceptability, the T_5 sample scored as "like very much" in the 9-point hedonic scale with the mean value of 8.07 ± 0.20, and T_6 and T_7 samples scored as "dislike slightly" in the 9-point hedonic

Table 8: Values of coefficients and statistical parameters for tray drying of paneer at 60°C.

Sample	Models	Parameter values	R^2 value	SSE	RMSE
Control	Page	$a = 0.137$; $b = 0.832$	0.9925	0.0222	0.0211
	Logarithmic	$a = 0.902$; $b = 0.076$; $c = 0.007$	0.9914	0.0257	0.0229
	Wang and Singh	$a = -0.054$; $b = 0.0007$	0.8692	0.3904	0.0883
	Midilli	$a = 0.992$; $b = 0.163$; $c = -0.001$; $d = 0.728$	0.9985	0.0044	0.0096
	Two-term exponential	$a = 0.842$; $b = 0.073$; $c = 1.348$	0.9965	0.0105	0.0146
	Henderson and Pabis	$a = 0.899$; $b = 0.078$	0.9912	0.0261	0.0228
6% OD	Page	$a = 0.162$; $b = 0.752$	0.9678	0.0885	0.0429
	Logarithmic	$a = 0.868$; $b = 0.061$; $c = -0.031$	0.9618	0.1052	0.0473
	Wang and Singh	$a = -0.052$; $b = 0.0006$	0.8179	0.5009	0.1022
	Midilli	$a = 1.024$; $b = 0.245$; $c = -0.003$; $d = 0.520$	0.989	0.0303	0.0256
	Two-term exponential	$a = 0.259$; $b = 0.662$; $c = 0.230$	0.979	0.0576	0.0350
	Henderson and Pabis	$a = 0.854$; $b = 0.068$	0.9604	0.1089	0.0476
12% OD	Page	$a = 0.188$; $b = 0.768$	0.9916	0.0220	0.0216
	Logarithmic	$a = 0.887$; $b = 0.104$; $c = 0.027$	0.9802	0.0517	0.0335
	Wang and Singh	$a = -0.060$; $b = 0.0008$	0.7773	0.5822	0.1113
	Midilli	$a = 1.027$; $b = 0.225$; $c = -0.0008$; $d = 0.684$	0.9941	0.0155	0.0185
	Two-term exponential	$a = 0.339$; $b = 0.388$; $c = 0.21$	0.9935	0.017	0.0192
	Henderson and Pabis	$a = 0.889$; $b = 0.092$	0.9772	0.0595	0.0355
22% OD	Page	$a = 0.150$; $b = 0.802$	0.9838	0.0447	0.0308
	Logarithmic	$a = 0.886$; $b = 0.068$; $c = -0.029$	0.9862	0.0381	0.0288
	Wang and Singh	$a = -0.055$; $b = 0.0007$	0.863	0.3779	0.0896
	Midilli	$a = 0.989$; $b = 0.196$; $c = -0.002$; $d = 0.632$	0.998	0.0055	0.0111
	Two-term exponential	$a = 0.181$; $b = 1.671$; $c = 0.392$	0.9928	0.02	0.0208
	Henderson and Pabis	$a = 0.873$; $b = 0.075$	0.9846	0.0425	0.0300
Surface OD	Page	$a = 0.222$; $b = 0.660$	0.9532	0.1103	0.0474
	Logarithmic	$a = 0.803$; $b = 0.053$; $c = -0.055$	0.9593	0.0959	0.0447
	Wang and Singh	$a = -0.053$; $b = 0.0007$	0.707	0.6903	0.1187
	Midilli	$a = 0.995$; $b = 0.347$; $c = -0.005$; $d = 0.370$	0.9954	0.0108	0.0152
	Two-term exponential	$a = 0.705$; $b = 0.059$; $c = 3.686$	0.9831	0.0397	0.0287
	Henderson and Pabis	$a = 0.774$; $b = 0.065$	0.9551	0.1058	0.0464

scale. These sensory results found in agreement with [44] who observed that the drying of paneer in different temperature and noted that the overall acceptability score was maximum in samples which dried at lower drying temperature.

3.2.7. Texture Profile Analysis of Paneer. Tables 11–13 explains the textural properties *viz.,* hardness, springiness, Cohesiveness, chewiness, resilience and fracturability of dried paneer. In Table 11, it clearly indicates a substantial change in values among the treatments. The samples dried at 50°C had hardness value in the range between 39306.26 ± 0.25 and 50191.26 ± 1.25 g. The Cohesiveness, chewiness and resilience values were more in 22% OD treated sample. From Table 12, the textural parameters show (P ≤0.01) highly significant difference between the 55°C temperature dried samples and hardness value in the range from 48438.56 ± 0.25 to 52535.83 ± 140.93 g. The samples dried at 60°C had hardness in the range from 51731.49 ± 0.28 to 55603 ± 157.11 g and statistically shows highly significant (P ≤0.01) difference between the samples as shown in Table 13.

In dried samples, the lower moisture content was recorded in higher drying temperature. So, the hardness value was higher in samples dried at 60°C compared to other temperature. In each temperature, the hardness value of OD treated and dried samples was higher than control dried sample. The osmotic pretreatment influences negatively (P ≤0.01) on hardness of the dried sample on all temperature. The osmotic

Table 9: L^*, a^*, and b^* values (mean ± SD) of dehydrated paneer samples.

Temperature	Sample	L^*	a^*	b^*	Whiteness index
	Fresh	87.18 ± 0.20^{k}	-0.129 ± 0.01^{ab}	15.69 ± 0.11^{a}	79.74
50°C	Control	74.47 ± 0.35^{e}	0.76 ± 0.03^{d}	27.82 ± 0.24^{g}	62.23
	6% OD	81.58 ± 0.63^{h}	0.43 ± 0.11^{c}	24.15 ± 0.26^{e}	69.62
	12% OD	84.00 ± 0.18^{i}	0.21 ± 0.03^{c}	20.29 ± 0.11^{d}	74.16
	22% OD	85.41 ± 0.23^{j}	-0.28 ± 0.03^{a}	18.99 ± 0.22^{c}	76.05
	Surface OD	85.54 ± 0.33^{j}	-0.37 ± 0.06^{a}	17.84 ± 0.39^{b}	77.03
55°C	Control	72.92 ± 0.04^{d}	3.61 ± 0.02^{h}	29.56 ± 0.02^{jk}	59.75
	6% OD	77.25 ± 0.02^{f}	3.36 ± 0.02^{g}	28.30 ± 0.02^{hi}	63.53
	12% OD	77.01 ± 0.04^{f}	2.39 ± 0.02^{f}	27.55 ± 0.02^{g}	64.04
	22% OD	79.74 ± 0.33^{g}	1.26 ± 0.04^{e}	26.72 ± 0.33^{f}	66.44
	Surface OD	80.77 ± 0.34^{g}	-0.02 ± 0.008^{b}	26.70 ± 0.32^{f}	67.10
60°C	Control	69.75 ± 0.67^{a}	5.33 ± 0.14^{i}	29.86 ± 0.31^{k}	57.16
	6% OD	70.17 ± 0.02^{a}	5.46 ± 0.06^{i}	29.03 ± 0.11^{ij}	58.02
	12% OD	71.07 ± 0.65^{bc}	6.11 ± 0.13^{j}	28.71 ± 0.35^{hi}	58.79
	22% OD	70.97 ± 0.43^{bc}	6.25 ± 0.13^{j}	27.87 ± 0.41^{g}	59.27
	Surface OD	71.44 ± 0.69^{c}	6.31 ± 0.13^{j}	28.23 ± 0.10^{gh}	59.35
F value		237.998^{**}	1014.418^{**}	330.757^{**}	

Average of three trials; **Highly significant ($P \leq 0.01$) at intervals. Superscripts with same letter indicate that the treatments are on par.

Figure 9: Control and OD-pretreated paneer cubes dried at 50, 55, and 60°C.

pretreatment leads to more moisture diffusion in drying and thus salt increased the hardness value. These results are accordance with [45]. The fracturability was seen in (P ≤0.01) surface OD treated sample among all the drying temperature. This might be due to surface OD treatment had high impact on WL during pretreatment and it makes brittle on the surface of paneer before the drying itself. Additionally, the EMC was also more in surface OD samples and it aids to make fracturability. The OD treatment had (P ≤0.01) high significant difference in springiness and cohesiveness of the sample. Additionally, the chewiness and resilience were positively correlated (P ≤0.01) with OD treatment. In 55°C dried samples, resilience showed no significant (P >0.05) difference among control and OD samples. The OD treatment prevent the physicochemical reactions and holds the EMC at final phase of drying. It helps to attain better textural parameter than control sample. The gumminess value of OD treated samples was higher than control, it had (P ≤0.01) high significant difference in all the temperature. As compared the gumminess property, the control sample was far better than OD samples. The milk fat is immiscible with moisture and it exhibits the gumminess nature. The OD samples had more moisture and so it has higher gumminess value than control sample.

In case of 60°C drying temperature, the springiness and chewiness values were not recognized in 12% OD treated sample and add on with cohesiveness, gumminess values were absent in 22% OD treated sample. This may be due to milk fat melting effect on 60°C during the drying time [44]. Similar type of textural changes on other food products were noted by [46, 47].

3.2.8. Proximate Composition of Paneer. By comparing the color, textural, and sensory analysis, the paneer samples dried at 50°C were superior among others. Therefore, the control and OD-treated samples dried at 50°C were subjected to nutritional analysis. The detailed nutritional characterization is represented in Table 14.

The OD pretreatment was ($P \leq 0.01$) positively correlated with the fat retention of paneer sample. The fat content was highly retained in the surface OD-treated sample which had fat content of 35.5 ± 0.20%, while the lowest retention was seen in the control sample with 29.2 ± 0.14%, respectively. The protein content had no correlation with OD treatment but exhibits ($P \leq 0.01$) high significant difference. The 12% OD-treated sample shows more protein retention among other samples with 39.5 ± 0.26%. The salt shows impact on fat and protein contents. The salt prevents the lipolysis and proteolysis activities, and it leads to increase the fat and protein retention in OD-treated samples. Similar

Table 10: Sensory evaluation (mean ± SD) scores of dehydrated paneer.

Temperature	Sample		Color and appearance	Flavour	Body and texture	Overall acceptability
50°C	Control	T_1	5.87 ± 0.27^{b}	5.73 ± 0.22^{abc}	6.07 ± 0.30^{abcd}	5.93 ± 0.30^{cd}
	6% OD	T_2	7.07 ± 0.24^{c}	6.07 ± 0.31^{bc}	6.53 ± 0.29^{cde}	6.53 ± 0.13^{de}
	12% OD	T_3	7.27 ± 0.22^{c}	6.47 ± 0.13^{c}	7.07 ± 0.26^{ef}	6.73 ± 0.33^{e}
	22% OD	T_4	7.80 ± 0.17^{cd}	7.73 ± 0.18^{d}	7.53 ± 0.13^{fg}	7.87 ± 0.19^{f}
	Surface OD	T_5	8.20 ± 0.17^{d}	8.00 ± 0.19^{d}	8.07 ± 0.59^{g}	8.07 ± 0.20^{f}
55°C	Control	T_6	5.80 ± 0.41^{b}	5.33 ± 0.30^{ab}	5.73 ± 0.15^{abc}	5.33 ± 0.30^{bc}
	6% OD	T_7	5.53 ± 0.30^{b}	6.00 ± 0.36^{bc}	5.20 ± 0.31^{a}	5.33 ± 0.27^{bc}
	12% OD	T_8	5.33 ± 0.28^{b}	5.33 ± 0.18^{ab}	6.93 ± 0.20^{def}	5.47 ± 0.36^{bc}
	22% OD	T_9	5.93 ± 0.26^{b}	5.80 ± 0.17^{abc}	5.60 ± 0.31^{abc}	6.00 ± 0.21^{cde}
	Surface OD	T_{10}	5.80 ± 0.29^{b}	6.00 ± 0.21^{bc}	7.27 ± 0.33^{efg}	6.00 ± 0.32^{cde}
60°C	Control	T_{11}	4.13 ± 0.09^{a}	4.93 ± 0.40^{a}	5.40 ± 0.28^{ab}	4.20 ± 0.10^{a}
	6% OD	T_{12}	4.20 ± 0.14^{a}	5.33 ± 0.43^{ab}	5.73 ± 0.36^{abc}	4.20 ± 0.14^{a}
	12% OD	T_{13}	5.27 ± 0.28^{b}	5.80 ± 0.36^{abc}	6.33 ± 0.34^{bcde}	5.07 ± 0.22^{b}
	22% OD	T_{14}	5.40 ± 0.34^{b}	6.00 ± 0.32^{bc}	5.87 ± 0.42^{abc}	5.33 ± 0.28^{bc}
	Surface OD	T_{15}	6.00 ± 0.27^{b}	5.47 ± 0.36^{ab}	6.53 ± 0.43^{cde}	5.40 ± 0.21^{bc}
F value			19.295^{**}	8.321^{**}	7.449^{**}	19.538^{**}

Average of three trials; **Highly significant ($P \leq 0.01$) at intervals. Superscripts with same letter indicate that the treatments are on par.

Table 11: Texture profile analysis (mean ± SD) of paneer samples dried at 50°C.

Sample	Hardness (g)	Fracturability (g)	Springiness	Cohesiveness	Gumminess (g)	Chewiness (g)	Resilience
Control	39306.26 ± 0.25^{a}	—	0.870 ± 0.007^{a}	0.440 ± 0.010^{b}	17304.10 ± 0.11^{b}	15076.36 ± 0.21^{a}	0.152 ± 0.012^{a}
6% OD	45984.50 ± 0.28^{c}	—	0.859 ± 0.013^{a}	0.522 ± 0.009^{c}	24066.30 ± 0.24^{d}	20671.36 ± 0.26^{c}	0.219 ± 0.000^{c}
12% OD	45965.84 ± 15.85^{c}	—	0.961 ± 0.014^{b}	0.367 ± 0.011^{a}	15959.23 ± 20.53^{a}	14959.00 ± 13.12^{a}	0.149 ± 0.012^{a}
22% OD	44670.39 ± 15.81^{b}	—	0.862 ± 0.025^{a}	0.599 ± 0.019^{d}	26781.95 ± 99.64^{e}	21761.39 ± 85.83^{d}	0.252 ± 0.009^{d}
Surface OD	50191.26 ± 1.25^{d}	48800.26 ± 0.25^{b}	0.846 ± 0.011^{a}	0.442 ± 0.021^{b}	22227.39 ± 0.30^{c}	18816.31 ± 0.28^{b}	0.171 ± 0.003^{b}
F value	3237.13^{**}	37676985917^{**}	12.45^{**}	281.49^{**}	10029.22^{**}	6534.19^{**}	43.24^{**}

Average of three trials. **Highly significant ($P \leq 0.01$) at intervals. Superscripts with same letter indicate that the treatments are on par.

Table 12: Texture profile analysis (mean ± SD) of paneer samples dried at 55°C.

Sample	Hardness (g)	Fracturability (g)	Springiness	Cohesiveness	Gumminess (g)	Chewiness (g)	Resilience
Control	48438.56 ± 0.25^{a}	—	0.850 ± 0.011^{a}	0.423 ± 0.005^{c}	20542.33 ± 0.28^{c}	17491.36 ± 0.30^{b}	0.168 ± 0.006^{a}
6% OD	52535.83 ± 140.93^{e}	—	0.973 ± 0.014^{d}	0.385 ± 0.006^{b}	19730.84 ± 85.67^{b}	17821.13 ± 47.39^{c}	0.167 ± 0.017^{a}
12% OD	49379.60 ± 154.92^{c}	—	0.933 ± 0.021^{c}	0.284 ± 0.006^{a}	13739.81 ± 134.31^{a}	12400.46 ± 131^{a}	0.396 ± 0.296^{a}
22% OD	48963.42 ± 0.25^{b}	—	0.895 ± 0.013^{b}	0.438 ± 0.009^{d}	21488.34 ± 0.29^{d}	19254.35 ± 0.29^{d}	0.172 ± 0.003^{a}
Surface OD	50433.30 ± 0.28^{d}	49698.42 ± 0.26^{b}	0.850 ± 0.015^{a}	0.479 ± 0.012^{e}	24179.31 ± 0.21^{e}	20588.82 ± 0.14^{e}	0.183 ± 0.004^{a}
F value	299.31^{**}	29923248116^{**}	21.46^{**}	320.21^{**}	2916.46^{**}	2494.190^{**}	$.568^{NS}$

Average of three trials. **Highly significant ($P \leq 0.01$) at intervals. ^{NS}Nonsignificant superscripts with same letter indicate that the treatments are on par.

observations were noted by the researchers [48, 49]. The carbohydrate content had ($P \leq 0.01$) highly significant difference between the control and OD samples. The OD-treated samples had low carbohydrate content compared to the control sample. Lactose is the source of carbohydrate in milk, and paneer had a minimal level of lactose due to its loss through whey during paneer production. Lactose level may be affected by osmotic pretreatment. The osmotic effect leads to expulsion of water during pretreatment which cause lactose reduction in OD-treated sample. Similar results were observed by [12]. The ash content was increased with increase in OD concentration of pretreatment and exhibited a ($P \leq 0.01$) highly significant difference. The solid gain during pretreatment was reason to increase the ash content in OD-treated samples. Similar types of changes on osmotic treatment were noted by [50].

Table 13: Texture profile analysis (mean ± SD) of paneer samples dried at 60°C.

Sample	Hardness (g)	Fracturability (g)	Springiness	Cohesiveness	Gumminess (g)	Chewiness (g)	Resilience
Control	53453.23 ± 71.27^b	—	0.884 ± 0.006^c	0.454 ± 0.015^c	22808.44 ± 107.01^c	19828.95 ± 46.99^b	0.177 ± 0.009^a
6% OD	55603.18 ± 157.11^c	—	0.998 ± 0.013^d	0.996 ± 0.004^e	55606.01 ± 164.00^e	55353.86 ± 147.82^d	0.225 ± 0.011^a
12% OD	55443.68 ± 68.69^c	—	—	0.362 ± 0.012^b	19315.10 ± 139.75^b	—	0.564 ± 0.020^b
22% OD	55486.20 ± 95.48^c	—	—	—	—	—	0.718 ± 0.131^b
Surface OD	51731.49 ± 0.28^a	51254.35 ± 0.31^b	0.870 ± 0.003^b	0.528 ± 0.017^d	27371.44 ± 0.240^d	23848.55 ± 0.29^c	0.216 ± 0.011^a
F value	335.93**	26004238046**	34264.07**	1569.28**	34650.48**	107254.79**	16.82**

Average of three trials. **Highly significant ($P \leq 0.01$) at intervals. Superscripts with same letter indicate that the treatments are on par.

Table 14: Proximate composition (mean ± SD) of dried paneer sample.

Sample	Moisture content (wt.%)	Carbohydrates (wt.%)	Protein (wt.%)	Fat (wt.%)	Ash (wt.%)
Control	15.26 ± 0.02^a	4.91 ± 0.05^e	39.3 ± 0.21^b	29.2 ± 0.14^b	8.80 ± 0.03^b
6% OD	15.71 ± 0.11^b	3.74 ± 0.02^d	38.8 ± 0.06^b	29.9 ± 0.06^c	8.93 ± 0.04^b
12% OD	14.47 ± 0.04^c	2.51 ± 0.08^c	39.5 ± 0.26^b	28.8 ± 0.10^a	9.47 ± 0.05^c
22% OD	16.54 ± 0.05^d	0.93 ± 0.05^a	36.5 ± 0.13^a	33.2 ± 0.08^d	9.56 ± 0.07^c
Surface OD	16.64 ± 0.05^e	1.42 ± 0.06^b	37.0 ± 0.44^a	35.5 ± 0.20^e	6.12 ± 0.06^a
F value	213.37**	2751.04**	27.25**	491.04**	663.67**

Average of three trials. **Highly significant ($P \leq 0.01$) at intervals. Superscripts with same letter indicate that the treatments are on par.

4. Conclusion

In this study, the OD pretreatment was applied to reduce the drying time and improve the quality characteristics of dried paneer. During pretreatment, the notable variations were observed in the water loss, solute gain, and weight reduction for different concentration. The water losses were found higher at a surface-treated paneer sample and lower in 6% OD-treated sample. The equilibrium moisture content level was observed higher in OD-treated samples. According to the findings, it was concluded that OD-treated sample had fasten drying rate and shorten drying time. In this study, it was found that the osmotic pretreated samples had higher moisture diffusivity and require low activation energy for drying. In modelling investigation, the Midilli model was observed as a good-fit model with R^2 value >0.99. Although the drying temperatures 55 and 60°C are advantageous in terms of drying time, it was observed that the color, texture, and sensory of the samples dried at 50°C were better preserved. So, 50°C was considered the best temperature to dry the paneer. The NaCl had significant impact on fat and protein retention. In the investigation of this study, it was concluded that OD pretreatment reduces the processing time and preserves the quality characteristics. However, 22% OD and surface treatment showed better results in dried condition, but it is important to remember that higher NaCl concentration may be leave saltiness taste in rehydration condition.

Data Availability

All data are available upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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