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Article

Effect of Pretreatment and Temperature on Drying Characteristics and Quality of Green Banana Peel

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Abstract: In banana cultivation, a considerable amount of the production is wasted every year because of various constraints present in the post-harvest management chain. Converting green banana pulp and peels into flour could help to reduce losses and enable the food sector to keep the product for an entire year or more. In order to use green banana fruit and peel flour in the food industry as a raw ingredient such as in bakery and confectionery items—namely biscuits, cookies, noodles, nutritious powder, etc.—it is essential to standardize the process for the production of the flour. As a result, the purpose of this study was to investigate the influence of pretreatment and temperature on the drying capabilities and quality of dried green banana peel. The green banana peel pieces were pretreated with 0.5 and 1.0% KMS (potassium metabisulfite), and untreated samples were taken as control, and dried at 40°, 50°, and 60 °C in a tray dryer. To reduce the initial moisture content of 90–91.58% (wb) to 6.25–9.73% (wb), a drying time of 510–360 min was required in all treatments. The moisture diffusivity (D_{eff}) increased with temperature, i.e., D_{eff} increased from $5.069–6.659 \times 10^{-8}$, $6.013–7.653 \times 10^{-8}$, and $4.969–6.510 \times 10^{-8}$ m^2/s for the control sample, 0.5% KMS, and 1.0% KMS, respectively. The Page model was determined to be the best suited for the drying data with the greatest R^2 and the least χ^2 and RSME values in comparison with the other two models. When 0.5% KMS-pretreated materials were dried at 60 °C, the water activity and drying time were minimal. Hue angle, chroma, and rehydration ratio were satisfactory and within the acceptable limits for 0.5% KMS-pretreated dried banana peel at 60 °C.

Keywords: green banana peel; pretreatment; quality; color; hot air drying; moisture diffusivity

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1. Introduction

Banana (*Musa paradaisica*) is a tropical and herbaceous plant of the Musacea family. Bananas are regarded as one of the most essential sources of energy in the diets of those who reside in tropical and humid climates. They are mainly cultivated for consumption as fresh fruit, although there are many other uses. According to the United Nations Food and Agriculture Organization (FAO), the annual worldwide production of bananas reached 119 million tons in 2020 [1]. The main byproduct of the banana processing industry is the peel, accounting for 35–40% of the fruit, which is underutilized, constitutes an environmental hazard, and is presently discarded as waste [2–8]. Currently, these peels are not used for anything else and are either disposed of as solid trash at high expense or used as animal feed. As a result, identifying applications for peels is important, if not critical, because they contribute to genuine environmental concerns.

In banana cultivation, considerable amount of the production is wasted every year because of various constraints present in the post-harvest management chain. Huge post-harvest losses occur in bananas, and it is necessary to convert them into value-added products to reduce losses. During green banana processing, the peel is separated from the fruit. It is treated as waste and discarded [9]. Value addition is required to reduce losses, enhance economic returns, and increase the utilization of all parts of the produce [10]. The conversion of green banana peel into flour could be one of the options. Green banana peel flour may be used as a base product for which the process must be standardized. One of the best and fastest ways to produce a value-added product is drying, which could be used as an initial treatment method to address several of these peels.

Drying is the process of removing moisture to a specified level by a simultaneous heat and mass transfer process under controlled conditions in order to minimize the volume of fruits or vegetables. Because of its simplicity, ease of operation, and cost-effectiveness, drying is one of the oldest ways of preservation and may be applied to banana fruit. Drying, a unit action, is used to reduce the water content of various agricultural goods. The purpose of decreasing water content is to reduce water activity to a level low enough to inhibit the growth of microbes, enzymatic processes, and other deteriorative activities [11]. In addition to these benefits, drying shrinks the bulk of foods, lowering the cost of packing, handling, storage, and transportation while also improving the ease of the handling and processing processes. Hot air drying extends shelf life and simplifies the manufacture of processed foods [12]. Hot air drying is thought to be a low-cost method of economically preparing vegetables and fruits [13]. Pretreatments in the food processing industry are helpful to minimize the detrimental impact on drying [13–16].

The mathematical modeling of the convective drying process utilizing diffusion theory may accurately reflect the pattern of water distribution inside specific agricultural commodities as a flawless geometric solid. A functional relationship between the diffusion coefficient and the moisture content is also required [17]. Drying kinetics research yields characteristics in the form of experimental diffusion coefficients that may be used to compute drying periods and, as a result, define the fundamental properties of drying equipment [9]. The best way to develop drying systems and examine complicated heat and mass transfer processes is to use mathematical models. The drying model explains experimental data variability, reduces experimentation errors, improves the drying process, reduces energy consumption, and increases profitability [18]. As a result, it promotes food preservation and later processing [19,20].

Banana peel flour has a good potential to be used in new products for different industrial and domestic uses. Peel is a potential source of antioxidants and phytochemicals. This banana peel flour can be substituted or mixed into various products such as noodles, cakes, etc. There is currently no information available on the drying conditions for preparing dried banana peels as a starting material for further processing [4]. As a result, the goal of this research was to look into the impact of pretreatment and drying air temperatures on the quality of green banana peel flour.

2. Materials and Methods

2.1. Materials

Physiologically matured fresh green bananas of Cv. *Nendran* stage 2 were collected from a local market in Udaipur, Rajasthan. Bananas were washed under running water to remove unwanted material. They were then peeled with a sharp-edged knife, and peel and pulp were separated. The peel was cut into 3 cm × 1 cm pieces for further processing. The moisture content of fresh green banana peel was tested using the method proposed by [21].

2.2. Pretreatment

One of the major problems associated with the green banana has been the development of a brown color after peeling. The traditional practice of the chip manufacturers was to put peeled fruits immediately in water. To avoid the browning of peeled fruits; different chemicals were tried as pretreatment by various researchers. However, there was no optimized concentration of chemicals given by researchers. The 0.5 and 1.0% concentration solutions of potassium metabisulfite (KMS) were prepared [15,22]. The green banana peel pieces were then dipped for 10 min in the KMS solution. The samples without immersion in the KMS solution were treated as control.

2.3. Tray Drying

The green banana peel samples, both control and pretreated, were subsequently dried in a tray dryer. (Model: 12 TD, make: Lab Line, Gujarat, India), loading density (kg/m^2): 1.089, number of heaters: 4, energy: 2.5 kWh, temperature range: up to 92 °C, thermostatic control: at three different temperatures: 40, 50, and 60 °C. The dryer was activated before roughly half an hour of experimentation to maintain an appropriate temperature in the drying chamber. The banana peel pieces were spread on a pre-weighed tray and then exposed to a tray dryer. Figure 1 shows the overall process design for the present study.

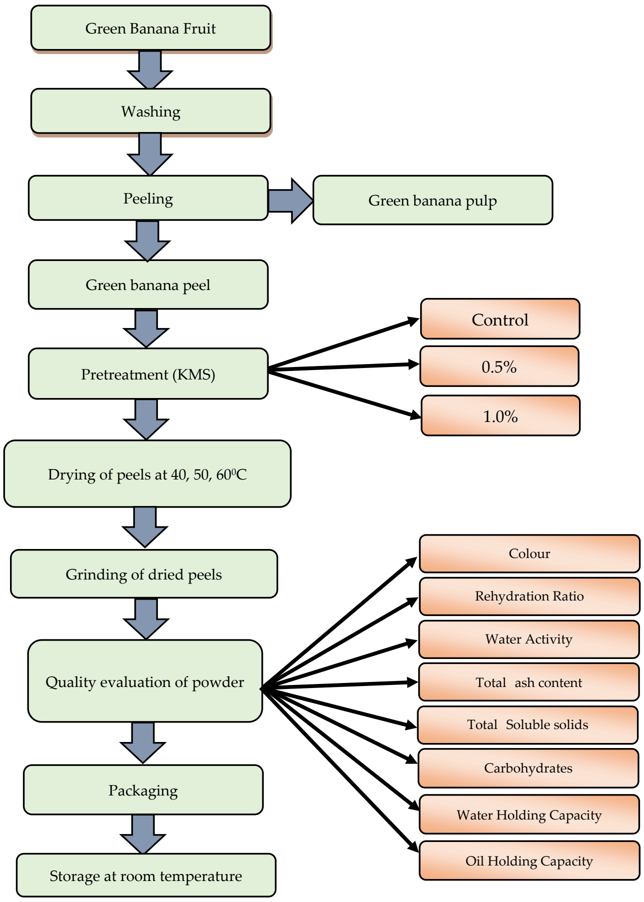

Figure 1. Overall experimental design.

2.4. Moisture Ratio

The moisture ratio is the ratio of the moisture content at any given time to the initial moisture content. It was calculated by Equation (1), as suggested by [23]:

$$MR = \frac{M}{M_o} \quad (1)$$

where

MR = Moisture ratio (dimensionless)
M = Moisture content at time, t (% db).
M_o = Initial moisture content (% db)

2.5. Drying Rate

The moisture content data collected throughout the trials was evaluated to assess the moisture loss from the banana peel samples over time. The drying rate of green banana peel samples was determined using the mass balance equation shown in Equation (2):

$$R = \frac{WML}{TI \times DM} \quad (2)$$

where

R = Drying rate, g of moisture evaporated per g of bone-dry matter per min
TI = Time interval
WML = Mass of moisture loss, g
DM = Dry matter

2.6. Moisture Diffusivity

The green banana peel pieces were considered an infinite slab (peel thickness of 3 mm) to solve Equation (3) for an infinite slab. The above equation can be rewritten as follows [24]:

$$MR = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}exp\left[\frac{-(2n+1)^2\pi^2 D_{eff}.t}{L^2}\right] \quad (3)$$

where,

D_{eff} = Effective diffusivity, m^2/s
M = Moisture content, g H_2O/g dry matter
MR = Moisture ratio, dimensionless
L = Characteristics dimension, i.e., thickness of peel, m
t = Time elapsed during drying (s).

A plot of experimental drying data of ln (MR) vs. drying time t yields the experimental values of effective diffusivity. It produced a straight line, and the slope of the line was employed in Equation (4) to compute moisture diffusivity:

$$Slope = \frac{\pi^2 D_{eff}.t}{L^2} \quad (4)$$

2.7. Mathematical Modeling

The Page, Henderson, Pabis, and logarithmic models, which have been widely used in drying modeling, were chosen to describe the drying process. The details of the mathematical models are given in Table 1. To select the optimum drying model, the coefficient of determination (R^2) was the most significant variable [9,25].

Table 1. Mathematical models used by different authors in drying of food materials.

Sr. No	Model Name	Mathematical Equation	Reference
1	Page	$MR = e^{(-ktn)}$	[26]
2	Henderson and Pabis	$MR = a.\ e^{(-kt)}$	[25]
3	Logarithmic	$MR = ae^{(-kt)} + C$	[27]

where,

k = Drying rate constant
n = Dimensionless empirical coefficient
t = Drying time, min
a and c = Empirical constants in drying models

Various statistical metrics, such as the reduced mean square of the deviation 2 and the root mean square error RMSE, were used to determine the quality of fit in addition to the coefficient of determination. R2 values should be greater and closer to one and two (Equation (5)) for excellent fit, while RMSE (Equation (6)) values should be lower [28]. The following parameters were calculated:

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(MR_{exp,\,i} - MR_{pre,\,i}\right)^2}{N - z} \quad (5)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(MR_{exp,\,i} - MR_{pre,\,i}\right)^2\right]^{1/2} \quad (6)$$

where *MR exp*,*i* and *MR pre*,*i* are the experimental and predicted dimensionless moisture ratios, respectively; *N* is the no. of observations; and *z* is the no. of drying constants.

2.8. Colour

The color values (L*, a*, and b*) of banana peel samples were measured using a Hunter Lab Colorimeter (Model CFLX/DIFF, CFLX-45) after drying, and the chroma and hue angle were determined using the calculations below [29]:

$$\text{Chroma} = \sqrt{\left(\text{a}^{*2} + \text{b}^{*2}\right)} \quad (7)$$

$$\text{Hue angle} = \tan^{-1}\left(\frac{\text{b}^*}{\text{a}^*}\right) \quad (8)$$

where,

a* = positive a* indicates as purple-red while negative a* as green on horizontal axis.
b* = horizontal axis b* indicates yellow (positive b*) or blue (negative b*).

2.9. Water Activity

Water activity is critical in the preservation of food goods. Low water activity provides better storage stability for food products [8]. The Lab Swift water activity meter (Novasina, Switzerland) was used to monitor water activity.

2.10. Rehydration Ratio

Approximately 5 g of dried sample was dissolved in 50 mL distilled water at 35 °C in a beaker and kept warm in a hot water bath for 5 h [30]. The beaker's water was drained out, and samples were taken. Tissue paper was used to soak up surface moisture before weighing it. The dried sample rehydration ratio was calculated using the following formula:

$$\text{Rehydration ratio} = \frac{\text{Weight of rehydrated sample (g)}}{\text{Test weight of dehydrated sample (g)}} \quad (9)$$

2.11. Carbohydrate

Carbohydrates are a vital source of energy and the primary component of bananas. They were calculated using the anthrone method proposed by [31].

A 100 mg sample was hydrolyzed in this manner by immersing it in a boiling water bath for 3 h with 5 mL of 2.5 N HCl and then cooling it to room temperature. The contents were neutralized with solid sodium carbonate until the effervescence stopped, and the volume was increased to 100 mL before centrifugation. After 0.9 mL of water and 4 mL of anthrone reagent were added to a 0.1 mL sample of it, the components were mixed and cooked for 8 min in a boiling water bath before being quickly cooled and measured for green to dark green hue at 630 nm using a digital spectrophotometer. A standard curve was plotted using glucose as a standard and the amount of carbohydrates present in the samples calculated:

$$\text{Carbohydrates in sample }(\%) = \frac{\text{Sugar value from graph (mg)}}{\text{Aliquot sample used (0.5 mL)}} \times \frac{\text{Total vol.of extract (mL)}}{\text{Wt. of sample (mg)}} \quad (10)$$

2.12. Water Holding Capacity (WHC) and Oil-Holding Capacity (OHC)

An amount of 1 g of dry material was mixed with 25 mL of distilled water or commercial oil and incubated at 60 °C for 1 h. The tubes were centrifuged at 3000 g for 20 min, the supernatant was decanted, and the tubes were allowed to drain at a 45° angle for 10 min. WHC and OHC were computed as g water or oil per g dry material, respectively, from the residue [32].

2.13. Total Soluble Solids

The total soluble solids content in the powder of green banana peel and pulp slices was determined by their dispersion in 8% *w*/*v* water stirred for 5 min and allowed to stand for 30 min. The TSS of the prepared slurry was measured using a digital hand refractometer [33].

3. Results and Discussion

3.1. Drying Characteristics of Green Banana Peel

3.1.1. Effect of Pretreatment on Drying of Green Banana Peel

The initial moisture content of banana peels was 900.6% (db), which increased to 1021.78% (db) after dipping them in potassium metabisulfite solution for 10 min. The final moisture content of dried banana peels ranged between 6.3% and 7.8% (db). The drying time of the banana peels was affected by air temperature, as shown in Table 2. When the drying temperature was raised from 40 to 50 °C, the drying time for the control sample was reduced from 510 to 480 min, with a 5.88% reduction, but when the temperature was further increased to 60 °C, the drying time was reduced to 420 min, with a 17.64% reduction in time compared to the 40 °C temperature.

Table 2. Drying time of green banana peel drying under different temperatures and pretreatments.

Pretreatment, %, KMS	Temperature, °C	IMC, % (db)	FMC, % (db)	Drying Time, Min	% Reduction in Drying Time
0 (Control)	40	928.4	8.8	510	--
	50	908.6	6.3	480	5.88
	60	911.8	6.2	420	17.65
0.5	40	916.7	9.1	450	--
	50	900.6	8.7	390	13.33
	60	914.8	8.0	360	20.00
1.0	40	1017.67	8.8	480	--
	50	1018.22	8.2	450	6.25
	60	1021.78	7.8	420	12.50

In a similar way drying time was reduced by 13.33 and 20.00% for 0.5% KMS-treated banana peel samples when the drying air temperature was raised from 40 to 50 °C and 50 to 60 °C, respectively. However, increasing the drying air temperatures from 40 to 50 and 60 °C for 1% KMS-treated banana peel samples resulted in a 6.25 and 12.50% decrease in drying time, respectively. Moisture content changed with drying time and temperature, as well as pretreatment. The drying time was drastically decreased. Comparing Figures 2–4, it is clear that though the initial moisture content in the control sample was minimum as compared to 0.5 and 1.0% KMS pretreatment, the time taken by samples to achieve the desired final moisture content was longer in the control sample than in the others. However, there was a significant decrease in drying time in 0.5% KMS pretreated samples as compared to control and 1.0% KMS pretreated samples.

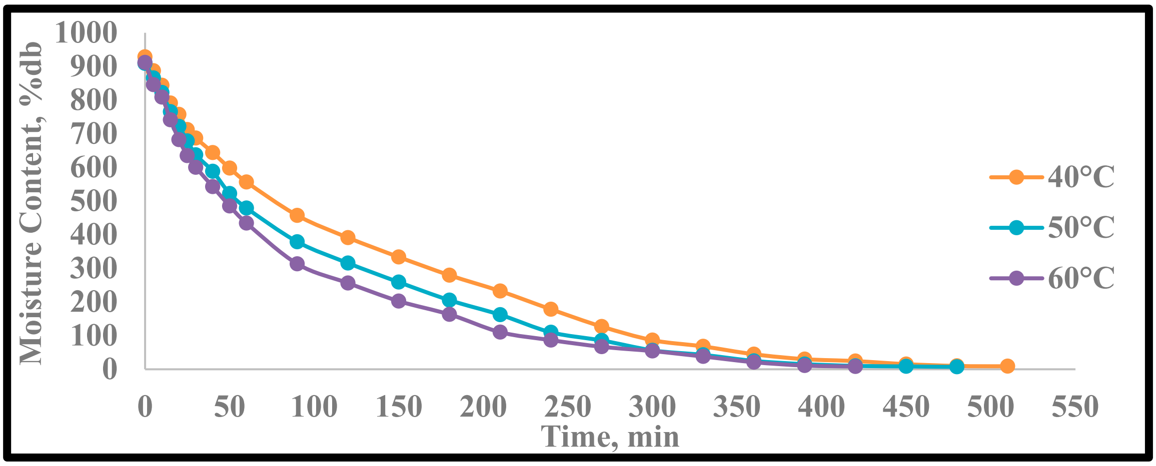

Figure 2. Variation in moisture content with drying time for untreated (control). Green banana peel at various drying air temperatures.

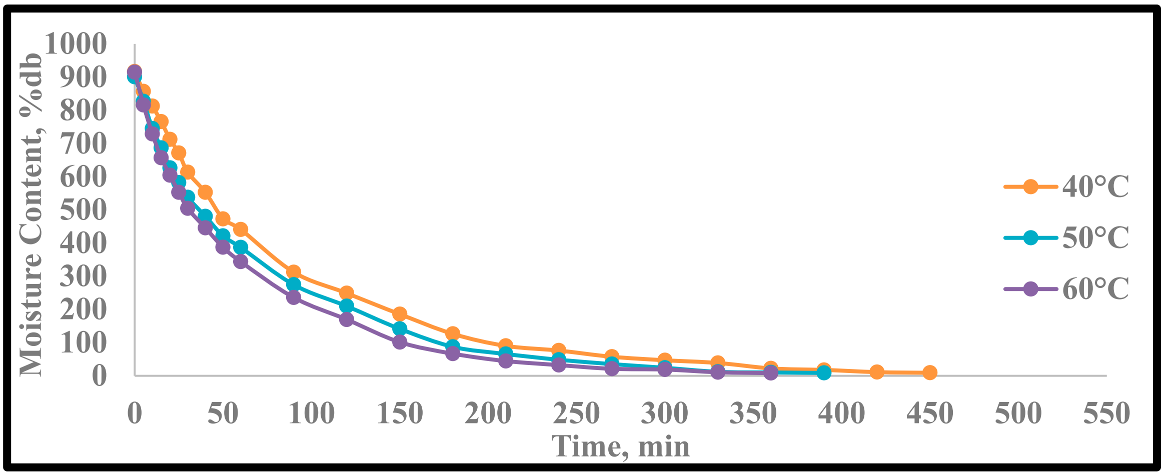

Figure 3. Variation in moisture content with drying time for 0.5% KMS. Green banana peel at various drying air temperatures.

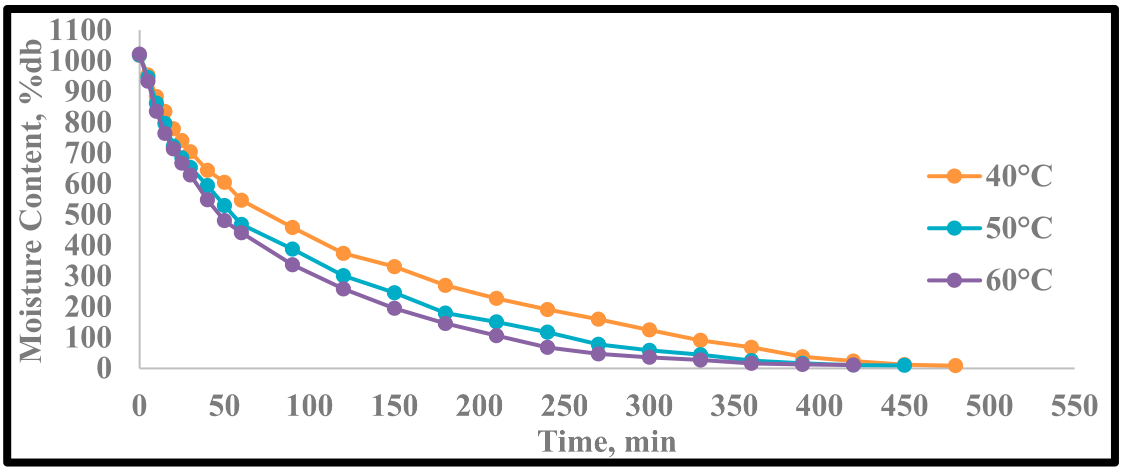

Figure 4. Variation in moisture content with drying time for 1.0% KMS. Green banana peel at various drying air temperatures.

At $p < 0.01$, both temperature and pretreatment had a significant effect on drying time. Figures 2–4 show the variation in moisture content, % (db), as a function of drying time. Moisture removal was fast initially, but as drying time progressed, the rate of moisture removal slowed down. Throughout the drying process, a falling rate profile was seen [9,34]. The constant rate period was absent for all the experiments, indicating that there was no surface moisture present on the green banana peel. For banana slices [35] and for banana peel [9] identical results were found.

Green banana peel samples took longer to dry at drying air temperatures of 40 °C and 50 °C than at 60 °C, as shown in Figures 2–4. The drying time was reduced as the drying air temperature increased. In all pretreatments, the drying time was longest at 40 °C and shortest at 60 °C. This demonstrated that as the drying air temperature increased, so did the rate of moisture removal. The drying process involves both heat and mass transport. Higher drying air temperatures provide greater drying capability and heat transfer capacity, resulting in quick moisture removal. Control samples needed more drying time than pretreatment samples to reach a safe moisture level. At higher drying air temperatures, less drying time was observed, which is in agreement with various researchers and for various fruits and vegetables, viz., banana peel and pulp [36]; pomegranate peel [37,38]; banana peel [25]; banana pulp with peel [5]; and pomelo peel [39].

3.1.2. Effect of Drying Air Temperature on Green Banana Peel Drying Characteristics

For all temperatures used for the present study, the moisture reduction in green banana peel with 0.5% KMS treatment was faster than in other samples, i.e., control and 1% KMS. Comparable results were obtained by [13] for French and false horn plantain slices. Similar findings were also found of an increase in KMS level increasing the initial moisture content of mango slices [40] with an increase in drying time. As the level of KMS increases, the initial moisture content of pretreated samples increases. The control and pretreated banana peels were dried until they had a final moisture content of 6.54–97.3% db.

3.1.3. Effect of Pretreatment and Drying Air Temperature on Drying Rate

Figures 5–7 illustrate the variation in drying rates between untreated and pretreated green banana peel samples. In all experiments, increasing the drying air temperature resulted in an increase in drying rate. Similarly, a higher rate of drying was noted for KMS-treated banana peels. The increase in drying rate with increasing drying temperatures could be due to higher moisture diffusivity [23].

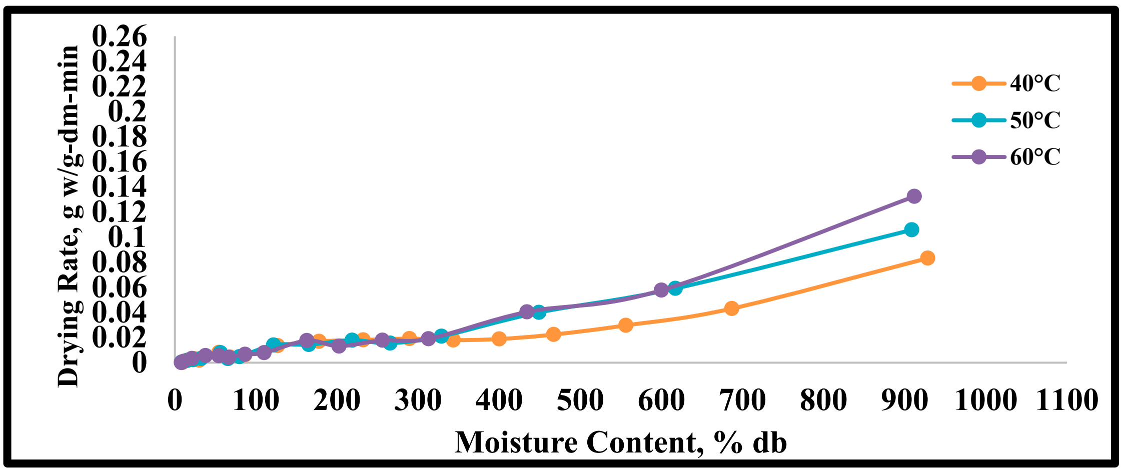

Figure 5. Variation in drying rate with moisture content at different air temperatures for untreated (control) green banana peel.

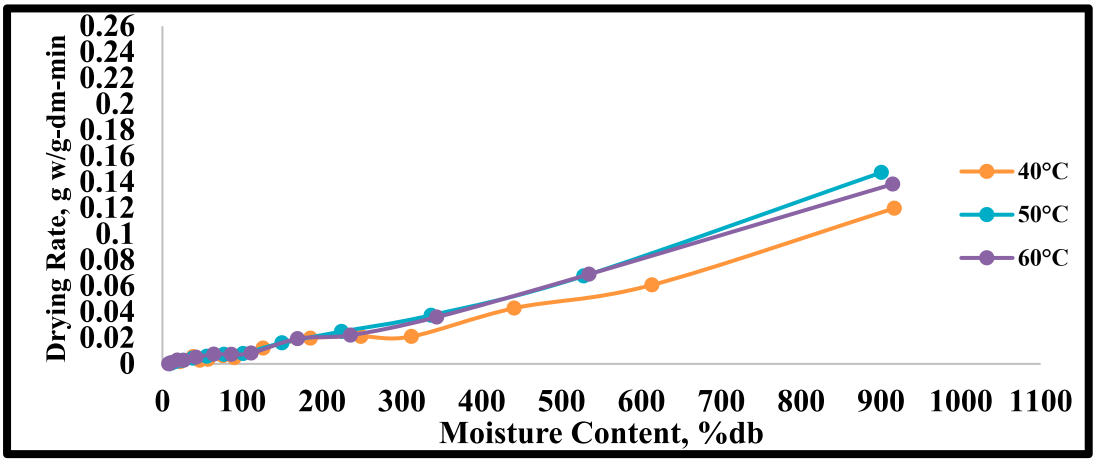

Figure 6. Variation in drying rate with moisture content at different air temperatures for 0.5% KMS treated green banana peel.

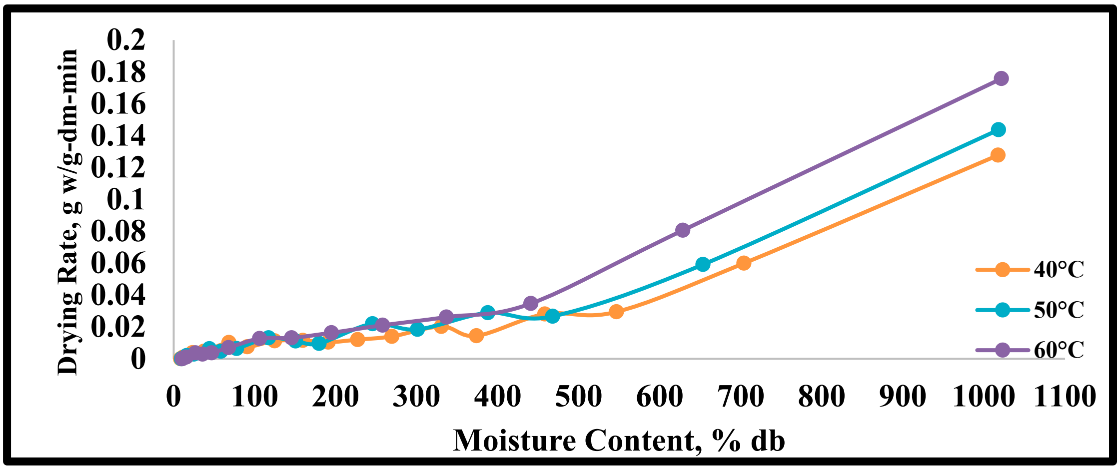

Figure 7. Variation in drying rate with moisture content at different air temperatures for 1.0% KMS treated green banana peel.

The maximum drying rate of 0.17 gw/g dm-min was observed for a 1.0% KMS sample at a 60 °C drying air temperature. It can be seen from Figure 1 that at the initial inception of the drying, the drying rate was higher and reduced with time as the moisture content of the product decreased. It can also be noted that in the initial period of 90–120 min, the drying rate for different air temperatures varied, but later on, as the drying continued, the rate of drying was found to be the same for all temperatures. The absence of a constant rate drying period was observed, and complete drying of samples occurred in a falling rate period for all temperatures and pretreatments. This was also confirmed by other researchers, that the typical drying curve for food products was in the falling rate period only. Similar findings were reported by [9,41] for banana peel, [37] for pomegranate peel, and also for some agricultural waste like olive bagasse [42], chicory root slices [43], apple pomace [44], and pomelo (Citrus Maxima) peel [39]. The average drying rate was greater at the start of the drying process for all drying temperature ranges, possibly due to evaporation and moisture from the peel surface, but it rapidly reduced with decreasing moisture content [38].

3.1.4. Moisture Diffusivity

Table 3 shows the values for effective moisture diffusivity for various drying air temperatures and pretreatment combinations. From the table, it is clear that as the temperature increased, effective moisture diffusivity also increased. The findings of the current study are consistent with those of [9,45] for banana peel. Increased air heat supply levels might cause accelerated moisture migration from the peel, leading to a rapid reduction in the moisture ratio [38]. Diffusion has governed internal mass flow, as shown by the constant decrease in moisture ratio [46].

The average moisture diffusivity (D-eff)avg of tray-dried green banana peel was found to be in the range of 5.069×10^{-8} to 6.659×10^{-8}, 6.013×10^{-8} to 7.653×10^{-8}, and 4.969×10^{-8} to 6.510×10^{-8} m^2/s for control, 0.5% KMS, and 1.0% KMS-treated samples, respectively. For drying food materials, these moisture diffusivity values are in the range of 10^{-8} to 10^{-12} m^2/s [47,48]. Similar results for effective moisture diffusivity were also reported by [49] for banana (1.75×10^{-8} m^2/s); by [50] for tofu (2×10^{-8} m^2/s); by [39] for pomelo (Citrus Maxima) peel (1.925–7.295 $\times 10^{-8}$ m^2/s).

The process temperature and pretreatment significantly affect moisture diffusivity at the 1% level of significance with a *p*-value of 0.000303 and 5.41×10^{-6} for pretreatment and temperature, respectively, with f value of 6.99.

Table 3. Moisture diffusivity in tray drying green banana peel.

Sr. No.	Pretreatment, %, KMS	Temperature, °C	Effective Diffusivity, m^2/s
1	0 (Control)	40	5.069×10^{-8}
2	0 (Control)	50	5.914×10^{-8}
3	0 (Control)	60	6.659×10^{-8}
4	0.5	40	6.013×10^{-8}
5	0.5	50	7.603×10^{-8}
6	0.5	60	7.653×10^{-8}
7	1.0	40	4.969×10^{-8}
8	1.0	50	6.460×10^{-8}
9	1.0	60	6.510×10^{-8}

3.2. Mathematical Modeling

The observed moisture ratio (MR) data were fitted to three thin layer drying models (Page, Henderson, and Pabis, as well as the Logarithmic model) in their linearized form using the regression approach (Table 4). The best model explaining the thin layer drying properties of green banana peel was chosen using the criterion of the highest coefficient of determination (R^2) and the lowest values of χ^2 and the root mean square error (RSME) [51].

The overall R^2 was found in the range of 0.8895 to 0.9978. Similarly, the overall values of χ^2 and RSME for all models were found in the range of 0.0001–0.0410 and 0.0404–0.4499, respectively. For all three drying temperatures and pretreatments, the Page model had strong coefficients of determination (R^2) and low values for root mean square error (RSME) and chi square (χ^2). Many researchers proposed the Page model to explain the drying characteristics of passion fruit peel [52], grapes [53], and "Xiem" banana peel [54].

Table 4. Values for model constants and statistical parameters used in convective drying of green banana peel.

Model	Pretreatment, % KMS	Air Temp., °C	Drying Constant				Statistical Parameters		
			k	n	a	b	R^2	χ^2	RMSE
Page	0	40	0.0096	0.9837	-	-	0.9792	0.0020	0.0096
	0	50	0.0138	0.9588	-	-	0.9931	0.0004	0.0207
	0	60	0.0158	0.9428	-	-	0.9841	0.0010	0.0229
	0.5	40	0.0139	0.9663	-	-	0.9961	0.0001	0.0133
	0.5	50	0.0209	0.9403	-	-	0.9978	0.0008	0.0091
	0.5	60	0.0193	0.9519	-	-	0.9949	0.0002	0.0152
	1.0	40	0.0173	0.8746	-	-	0.9772	0.0002	0.0355
	1.0	50	0.0195	0.9009	-	-	0.9800	0.0001	0.0320
	1.0	60	0.0241	0.8793	-	-	0.9913	0.0002	0.0228

Table 4. *Cont.*

Model	Pretreatment, % KMS	Air Temp., °C	Drying Constant				Statistical Parameters		
			k	n	a	b	R^2	χ^2	RMSE
Henderson and Pabis	0	40	0.0082	-	1.3338	-	0.9353	0.0410	0.2019
	0	50	0.0135	-	1.0550	-	0.9691	0.0020	0.0458
	0	60	0.0134	-	1.1987	-	0.8895	0.0120	0.1113
	0.5	40	0.0121	-	1.0653	-	0.9740	0.0020	0.0437
	0.5	50	0.0165	-	1.1588	-	0.9946	0.0090	0.0930
	0.5	60	0.0154	-	1.0380	-	0.9749	0.0020	0.0404
	1.0	40	0.0100	-	1.1587	-	0.9024	0.0130	0.1142
	1.0	50	0.0141	-	1.0711	-	0.9331	0.0050	0.0673
	1.0	60	0.0131	-	1.0249	-	0.9818	0.0030	0.0543
Logarithmic	0	40	-	-	1.5127	−0.2411	0.9700	0.0150	0.1218
	0	50	-	-	1.4479	−0.2408	0.9866	0.0110	0.1029
	0	60	-	-	1.4345	−0.2407	0.9878	0.0110	0.1037
	0.5	40	-	-	1.4562	−0.2453	0.9820	0.0120	0.1092
	0.5	50	-	-	1.3672	−0.2397	0.9835	0.0090	0.0972
	0.5	60	-	-	1.3909	−0.2446	0.9873	0.0100	0.0989
	1.0	40	-	-	1.4286	−0.2279	0.9837	0.0100	0.0997
	1.0	50	-	-	1.3867	−0.2304	0.9919	0.0080	0.0890
	1.0	60	-	-	1.3559	−0.2303	0.9916	0.0070	0.0844

3.3. Properties of Dried Banana Peel

The moisture content of prepared dried green banana peel powder was found to be in an acceptable range of less than 20% as per the FSSAI (Food Safety Standards Authority of India) norms. Three replicated sample data were collected, and average values were reported. From Table 5, it can be observed that the L* value was higher for 0.5% KMS-treated samples as compared to green banana peel dried without any pretreatment, i.e., control. Additionally, when compared to samples dried at high temperatures, low temperature samples had brighter colors (higher L* values). The L* value was found in the range of 35.69 to 58.28, and a* value was found in the range of 2.12 to 4.19. The minimum value of a* indicated more retention of green color in the dried samples. The chroma value was found in the range of 7.60 to 22.04. From the observations, it can be interpreted that the pretreated dried green banana samples retained L*, a*, and b* values. The breakdown of pigments, polyphenol oxidation, along with non-enzymatic browning reactions, including caramelization and the Maillard reaction taking place during the drying process, can all be used as reasons for the change in color [4].

The water activity of dried samples was found to be in the range of 0.278 to 0.412, and it decreased with the drying air temperatures. The variations of water activity might be due to the considerable loss in moisture content with the increase in drying time and drying air temperature. Spoilage of microorganisms cannot take place at the lower water activity. The results for water activity are in agreement with the trends obtained by [8] for banana.

Rehydration is a vital dried product quality attribute. The rehydration characteristics describe the physical and chemical changes that occur during the drying process as a result of the dried product's composition, drying conditions, and pretreatments [30]. The rehydration ratio for dried green banana peel was found to be in the range of 1.15–1.45. The rehydration ratio increased with temperature.

The total ash content of green banana peel powder was found to be in the range of 11.87–13.26%. The drying air temperature and the KMS treatment both had an effect on the overall ash content. The total ash content may be affected by the increase in temperature and pretreatment [55].

Table 5. Selected properties of dried green banana peel samples.

Parameter		Control (0% KMS)			0.5% KMS Treated			1.0% KMS Treated		
		40 °C	50 °C	60 °C	40 °C	50 °C	60 °C	40 °C	50 °C	60 °C
Color	L*	45.35 ± 0.07	38.26 ± 0.029	35.69 ± 0.051	58.28 ± 0.07	56.56 ± 0.049	44.19 ± 0.088	47.83 ± 0.088	51.25 ± 0.099	47.83 ± 0.099
	a*	3.01 ± 0.037	3.12 ± 0.104	3.50 ± 0.102	3.04 ± 0.057	2.79 ± 0.080	3.37 ± 0.102	2.12 ± 0.054	2.20 ± 0.049	4.19 ± 0.057
	b*	6.98 ± 0.08	7.00 ± 0.037	6.99 ± 0.135	16.12 ± 0.036	15.25 ± 0.054	9.70 ± 0.059	10.32 ± 0.037	15.16 ± 0.041	21.64 ± 0.057
Chroma		7.60 ± 0.182	7.66 ± 0.059	7.81 ± 0.067	16.40 ± 0.043	15.50 ± 0.09	9.70 ± 0.083	10.53 ± 0.054	15.31 ± 0.059	22.04 ± 0.115
Hue angle		1.16 ± 0.051	1.15 ± 0.054	1.10 ± 0.142	1.38 ± 0.051	1.39 ± 0.049	1.23 ± 0.059	1.36 ± 0.045	1.42 ± 0.059	1.37 ± 0.065
Water activity		0.412 ± 0.005	0.401 ± 0.007	0.341 ± 0.005	0.318 ± 0.005	0.291 ± 0.004	0.278 ± 0.004	0.351 ± 0.004	0.344 ± 0.004	0.301 ± 0.002
Rehydration ratio		1.15 ± 0.043	1.26 ± 0.045	1.35 ± 0.029	1.19 ± 0.042	1.33 ± 0.024	1.41 ± 0.041	1.22 ± 0.029	1.35 ± 0.037	1.45 ± 0.022
Total ash content		13.26 ± 0.033	13.24 ± 0.033	13.18 ± 0.029	12.87 ± 0.041	12.59 ± 0.037	12.41 ± 0.043	12.14 ± 0.029	12.00 ± 0.029	11.87 ± 0.054
TSS		1.39 ± 0.022	1.43 ± 0.033	1.46 ± 0.043	1.42 ± 0.029	1.48 ± 0.016	1.51 ± 0.024	1.49 ± 0.067	1.54 ± 0.036	1.61 ± 0.029
Carbohydrates		51.11 ± 0.088	51.21 ± 0.051	51.32 ± 0.016	51.47 ± 0.037	51.55 ± 0.067	51.49 ± 0.037	51.69 ± 0.065	51.86 ± 0.029	51.71 ± 0.029
Water-holding capacity, g water/g dry sample		4.26 ± 0.041	4.37 ± 0.033	4.44 ± 0.016	4.87 ± 0.024	4.94 ± 0.016	5.10 ± 0.045	5.14 ± 0.033	5.23 ± 0.029	5.28 ± 0.032
Oil-holding capacity, g oil/g dry sample		0.61 ± 0.016	0.64 ± 0.043	0.69 ± 0.022	0.67 ± 0.029	0.71 ± 0.29	0.74 ± 0.016	0.70 ± 0.024	0.75 ± 0.033	0.78 ± 0.067

Note: Values are means ± standard deviations of three replicate measurements.

Total soluble solids (TSS) were found in the range of 1.39–1.61°Brix. TSS is greatly affected by the KMS treatment. From Table 5, an increase in TSS with simultaneous increments in temperature and KMS% was observed. Carbohydrates were found in the range of 51.11–51.86%. The carbohydrate content of dried green banana peel powder was higher in KMS-treated samples as compared to untreated samples.

The dried green banana peel's water holding capacity (WHC) was determined to be in the range of 4.26–5.28 g water/g dry sample. WHC was lowest in the untreated samples and highest in the KMS-treated ones. Because of its high water-holding capacity, it might be used as a thickening agent for liquid and semi-liquid foods [56].

The oil holding capacity of dried green banana peel was found to be in the range of 0.61–0.78 g oil/g dry sample. The flours' high oil absorption abilities imply that they might be beneficial in food preparations involving oil mixing, such as bread products, where oil is an important element [56].

Since drying time and quality factors are crucial in the drying of food goods. The water activity and drying time were at a minimum while other quality parameters were within acceptable ranges when materials were pretreated with 0.5% KMS dried at 60 °C. The outcomes demonstrated that the powdered banana peel had excellent parameters. As a result, it could then be used in a variety of bakery and confectionery items, including biscuits, cookies, noodles, nutritious powder, etc.

4. Conclusions

The drying behavior of green banana peel dried with and without KMS pretreatment was studied here. The effects of pretreatments (control, 0.5% KMS, and 1.0% KMS) and hot air drying at different temperatures (40, 50, and 60 °C) on the drying kinetics and quality attributes of banana peel in terms of TSS, WHC, OHC, rehydration ratio, total ash content, water activity, and color (L*, a*, b*) were investigated. The drying time for green banana peel was found to be between 360 and 510 min. When compared to control samples, the 0.5% KMS-pretreated samples dried faster. The entirety of the drying process occurred within a decreasing rate period. As the temperature increased the effective moisture diffusivity, more pretreatment samples revealed effective moisture diffusivity. The Page model was found to best fit the experimental data. The color values decreased with temperature; however, retention of color was found in 0.5% KMS-pretreated samples. The water activity was found to be low in pretreated samples, while the rehydration ratio was found to be acceptable for 0.5% KMS pretreated samples dried at 60 °C with good retention of color and minimum water activity. Because drying time and quality factors are critical in the drying of food products, in the current investigation, the shortest time required for drying green banana peel was at 60 °C with samples pretreated with 0.5% KMS, while quality metrics were well retained. The results showed that the prepared banana peel had good quality parameters. Hence, it can be subsequently utilized in various bakery and confectionary products such as biscuits, cookies, cakes, noodles, nutritional powder, etc. As stated, banana peel is considered as waste, but it contains many nutritional compounds. Hence, currently it is gaining popularity. Researchers have made gluten-free cakes with dried green banana peel flour. Physical, sensory, and other investigations revealed that substituting 5% and 10% green banana peel flour was possible without affecting gluten free cake volume, specific volume, density, or baking loss. Noodles were prepared by researchers using 40–60% of peel flour incorporated as raw material. This incorporation did not affect the quality of the noodles. In preparation of cookies, wheat flour can be replaced with green banana peel flour by up to 15%.

5. Practical Applications

The post-harvest losses in bananas are high due to improper handling and storage. The green banana peel is considered as waste and is generally dumped in the soil or used as feed. Green banana peel is high in dietary fiber, protein, essential amino acids, polyunsaturated fatty acids, potassium, and a variety of bioactive substances, all of which may contribute to the nutritional quality of a variety of diets. Banana peel flour is high in soluble fiber, water retention, and swelling capacity. Hence, the drying of green banana peel would be useful to enhance profits, as there is scope for dried green banana peel powder in the bakery and confectionary industries such as the main ingredient in the preparation of biscuits, cookies, noodles, and nutritional powder, etc.

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