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Drying kinetics of banana peel

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Abstract
Drying of blanched banana peel was carried out in tray dryer. The drying experiments were performed at two different temperatures and a constant air velocity of 0.5 m/s. To select a best model, five different thin layer drying models were fitted to experimental data. Nonlinear regression procedure was used to fit five different models. The models were compared with experimental data of banana peel drying at air temperature of 60 °C and 70 °C. The best thin layer drying model was selected using the coefficient of determination (R^2), chi-square ($\mathcal{X}^2$) and Root Mean Square Error (RMSE). The highest value of R^2 (0.99640, 0.99652), the lowest of chi-square($\mathcal{X}^2$) (0.000218, 0.000231) and RMSE (0.014778, 0.015177) at temperature of 60 °C and 70 °C indicated that the Logarithmic and Henderson and Pabis model is the best mathematical model to describe the drying behaviour of banana peel.

Keywords: Drying kinetics, Banana peel, mathematical modelling, tray dryer

1. Introduction

Bananas (Musa sp.) are one of the most important tropical fruits consumed worldwide by people of all age groups. The nutritional and functional properties of bananas are known to provide good health. Nutritionally, bananas contain available carbohydrates which provide energy, vitamins B and C, and significant amounts of potassium and magnesium and amino acids. The peels of banana also contain carbohydrates, proteins, and fiber in significant amounts, making it an ideal substrate for production of value added products. Assuming that banana peels account for only 30% of the total fruit weight and have 20% dry matter, it contains minerals and various amino acids like aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, cystine, valine, methionine, isoleucine, leucine, phenylalanine, lysine and arginine. To the best of our knowledge no past research was conducted to investigate the drying kinetics of banana peel in hot air drying. In the view of the health promoting properties and high nutritional benefits of banana peel, the present study was carried out to observe the effect of different temperatures on drying characteristics of banana peel and to select the best mathematical model to observe the drying behavior of the banana peel.

2. Materials and Methods
2.1 Drying experiment
The peels of ripened bananas were collected from a vendor of local market. The peels was cut into the slices and blanched. The drying experiments carried out in a tray dryer at selected two air drying temperatures (60 and 70 °C) to obtain the drying characteristics of banana peel. Air velocity was set at 0.5 m/s. When the dryer reached steady state conditions (i.e. when desired temperature was reached) the sliced banana peels were distributed onto the trays. Moisture loss was recorded at every 15 min intervals during drying. Drying was continued until the moisture content of the sample reached to the equilibrium moisture content about 13-15% (wb) (Surojanametakul *et al.*, 2002). The drying was continued till weight became constant and experiments were conducted in duplicates.

2.2 Mathematical modeling of drying curves
The moisture ratio (*MR*) of banana peel during drying experiments was calculated using the following Equation
$MR = (M-M_e)/ (M_0-M_e)$

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Where M, M_o, and M_e are moisture content at any drying time, initial and equilibrium moisture content (kg water/kg dry matter), respectively.

Data obtained from the measurements of weight in a test was used for the analysis of drying kinetics of materials need to be changed first in the form of moisture content data. The moisture content was expressed as a percentage wet basis and then converted to moisture ratio. The experimental drying data for banana peel were fitted to the exponential model thin layer drying models as shown in Table 1 by using non-linear regression analysis.

Table 1: List of models with references

S. No	Model Name	Type	Reference
1	Newton	MR=exp(-kt)	Mujumdar (1987)
2	Page	MR=exp(-kt^n)	Diamante and Munro (1993)
3	Logarithmic	MR=a exp(-kt) +c	Yagcioglu *et al.*(1999)
4	Henderson and Pabis	MR=a exp(-kt)	Zhang and Litchfield (1991)
5	Wang and Singh	MR=1+at+bt^2	Wang and singh (1978)

The regression analysis was performed using the STATISTICA computer program. In Non-linear regression, the parameters used to evaluate goodness of fit of the mathematical models to the experimental data are coefficient of determination (R^2) and the reduced chi-square ($\mathcal{X}^2$) was used for data analysis. The higher value for R^2 and the lower values for $\mathcal{X}^2$ and root mean square error analysis (RMSE) indicate the better fitness of model (Sarsavadia *et al.*, 1999) [9]. These parameters were calculated as follows:

$$R^2 = 1 - \left[\frac{\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i})^2}{\sum_{i=1}^{N}(\overline{MR}_{pre} - MR_{exp,i})^2} \right]$$

$$Chi\ Square = \chi^2 = \sum_{i=1}^{N} \left[\frac{(MR_{Experimental\ Value} - MR_{predicted\ value})^2}{(N-n)} \right]$$

Where, n = no. of unknown and N= Data point measured

$$RMSE = Root\ mean\ square\ error = \sum_{i=1}^{N} \left[\sqrt{\frac{(MR_{Experimental\ value} - MR_{predicted\ value})^2}{N}} \right]$$

The mean relative deviation $E\ (\%)$ is an absolute value that was used because it gives a clear idea of the mean divergence of the estimated data from the measured data.

$$E(\%) = \frac{100}{N} \sum_{i=1}^{N} \left| \frac{MR_{Experimental\ Value} - MR_{predicted\ value}}{MR_{Experimental\ value}} \right|$$

The values of E less than 5.0 indicate an excellent fit, while values greater than 10 are indicative of a poor fit.

3. Results and Discussion

The drying process was stopped no change in the weight of sample of banana peel was observed. At this point moisture content was decreased. Moisture content data was converted to moisture ratio then fitted to the five thin layer drying models. Table 2 showing the results of fitting the experimental data to the thin layer drying models with best fitting model in bold type for temperature of 60 and 70 °C. The drying rate decreased continuously throughout the drying period. The constant rate period was absent and the drying process of banana peel took place in falling rate period. The moisture ratio reduced exponentially as the drying time increased (Doymaz, 2007) [4]. Continuous decrease in moisture ratio indicates that diffusion has governed the internal mass transfer. A higher drying air temperature decreased the moisture ratio faster due to the increase in air heat supply rate to banana peel and the acceleration of moisture migration (Demir *et al.*, 2004) [2].

**Table 2:** the fitness of different models at different temperatures

Model	Temperature °C	Coefficient	Coefficient Of Determination (R^2)	Chi-Square (χ^2)	Rmse	E%
Newton	60	K=0.002258	0.98510	0.000905	0.238748	7.727946
	70	K=0.002427	0.98289	0.001133	0.033654	5.213993
Page	60	K=0.002494 n=0.983696	0.98518	0.009021	0.03002	7.262423
	70	K=0.000929 n=1.161446	0.99268	0.000484	0.022007	3.371934
Logarithmic	60	K=0.003234 a=0.981314 c=0.113281	0.99640	0.000218	0.014778	2.795789
	70	K=0.002713 a=1.091012 c=0.002017	0.99652	0.000231	0.015179	2.497142
Wang and Singh	60	a=0.002006 b=0.001001	0.98817	0.000718	0.026801	7.080818
	70	a=0.002047 b=0.000012	0.99004	0.000659	0.025673	3.136054
Henderson and pabis	60	K=0.002347 a=1.033488	0.98680	0.000802	0.028318	8.48627
	70	K=0.002703 a=1.092349	0.99652	0.000231	0.015177	2.519419

From Table 2 it can be concluded that the best models for the temperature 60 and 70 °C are Logarithmic and Henderson and Pabis with 0.99640, 0.000218, 0.014778 and 0.99652, 0.000231, 0.015177 values for R^2, χ^2 and RMSE respectively.

It can be seen that different initial moisture contents resulted in longer drying times for samples dried at 60 and 70 °C. Greater initial drying rate for the banana with the higher moisture content. Thus, higher initial moisture content in food resulted in a higher drying rate as expected. This causes rapid decrease in moisture content of the banana peel. High temperature accelerated the evaporation of moisture near the surface better than low temperature thus drying time could be reduced. The results of drying at 60 °C agreed with the reports of Sabarez, Price and co-workers (1997) [8] for drying plum of different initial moisture contents at 70 °C. Thus, a higher drying air temperature produced a higher drying rate and consequently the moisture ratio decreased.
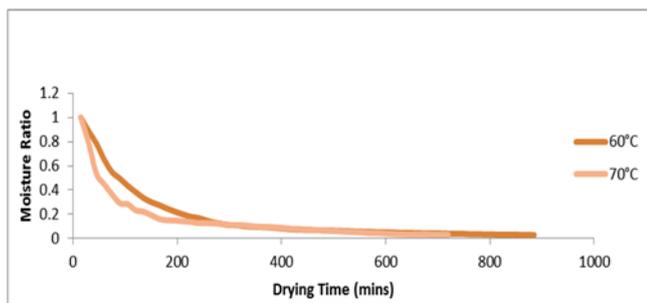
Fig 1: Moisture ratio versus drying time of banana peel at different temperatures
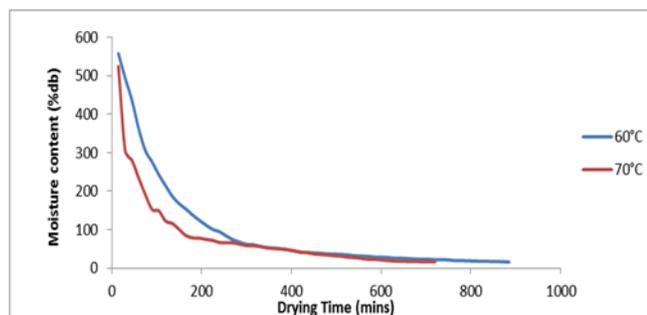
Fig 2: Drying curves of banana peel at different temperature

4. Conclusion
Drying using a hot-air chamber was tested on samples of banana peel. Drying kinetics curves of drying banana peel demonstrated that drying at 60 °C and 70 °C were the optimum values for drying banana peel with the appropriate equations using the logarithmic model and Henderson and pabis model with R^2 of 0.9964 and R^2 of 0.9965. According to the results which showed the highest average values of R^2 and the lowest average values of chi-square and RMSE, it can be stated that the logarithmic model and Henderson and pabis model was best fitted model to describe the drying characteristics of the samples.

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