Effects of pre-treatments on drying kinetics of sweet potato slices

Rufus Rotimi Dinrifo※

(*Agricultural Engineering Department*, *School of Engineering*, *Lagos State Polytechnic*, *Ikorodu. 23401. Lagos Nigeria*)

Abstract: In this study, thin layer drying kinetics of sweet potato slices was investigated by using a hot air convective dryer operated at 50, 60, 70 and 80℃. Different treatments were given to samples of sweet potato slices: some were blanched in hot water at 100℃ (WAT), others were dipped in sodium meta-bisulphite (SMB), while the rest were left untreated (UNT). The experimental drying data were fitted to four well known drying models: the Modified Page 1, Wang and Singh, Two Term Exponential and Approximation of Diffusion. Among the four models considered, the Modified Page 1 was found to best describe the drying kinetics of sweet potato slices. The effective moisture diffusivity of the samples was in the range from 7.76×10^{-9} m^2/s to 1.2×10^{-8} m^2/s. The values for activation energy, the energy necessary for the onset of the drying process, were 9.13 kJ/mol, 11.25 kJ/mol and 17.5 kJ/mol for WAT, SMB and UNT, respectively, indicating that it was easier to induce the water release process in the WAT and the SMB compared to the UNT samples.

Keywords: sweet potato, pre-treatment, drying kinetics, drying models

Citation: Rufus Rotimi Dinrifo. 2012. Effects of pre-treatments on drying kinetics of sweet potato slices. Agric Eng Int: CIGR Journal, 14(3): 136－145.

1 Introduction

Sweet potato (*Ipomea batatas*) is a low-input tropical crop that has great nutritive and agronomic characteristics (Woolfe, 1992). Currently, Nigeria is the largest producer in Africa and the second largest producer of sweet potato tubers in the world, after China (FAO, 2008). Sweet potato is rich in complex carbohydrates, dietary fibre, iron, calcium and vitamins. The tubers are most frequently boiled, fried or baked. They can also be processed to make starch for ethanol production and as partial flour substitute for cake or bread producing. Many food products such as tomato sauce, ketchup, dried-cake, spongy cake, and biscuit utilize sweet potato as part of their ingredients (Zuraida, 2003). New uses such as for the production of noodles, cookies, doughnuts could increase the demand for sweet potatoes (Indrasari et al.,1994).

Sweet potato tubers once harvested deteriorate rapidly, mainly due to physiological changes and mechanical damage during harvesting, transportation and handling. Besides, the tubers exhibit no dormancy and are susceptible to insect infestation. The very short storage life after harvest has been recognised as a limitation to the cultivation of the crop (Okaka, 1997). As a result, growers prefer to convert the tubers into more stable forms such as chips and flours so as to prolong the shelf life (Oyewole, 2002; Ayinde and Dinrifo, 2001). This is usually done by cutting the tubers into slices and drying them in the open sun or in an air-dryer.

Prior to drying, most food products are usually subjected to a some form of pre-treatments, among which are hot water blanching and sulphiting. Blanching helps to inactivate enzymes that may lead to quality degradation (Moreno-Perez, Gasson-Lara and Ortega-Rivas, 1996) and to improve the acceptability of the final product (Babajide et al., 2006). According to Senadeera et al., (2000) blanching also leads to structural softening and hence facilitates moisture removal. Hot

Received date: 2010-01-22 **Accepted date:** 2012-06-04

*** Corresponding author: Rufus Rotimi Dinrifo,** Agricultural Engineering Department, School of Engineering, Lagos State Polytechnic, Ikorodu. 23401. Lagos Nigeria; Email: rdinrifo@yahoo.com

water blanching and the use of chemicals such as sulphur, methyl and ethyl ester emulsions or alkaline pre-treatment in aqueous solutions of sodium hydroxide, sodium chloride, potassium and sodium carbonate, calcium chloride have been applied to overcome the waxy or fibrous barrier on roots, fruits and vegetables (Krokida and Moroulis, 2001; Doymaz, 2007; Doymaz and Pala, 2002).

Knowledge of the drying kinetics of biological materials is essential to the design, optimization and control of drying processes. Many authors have reported the drying characteristics of various agricultural or food products. Among these are the reports on tomato (Sacilik, Keskin and Elicin, 2006), yam (Sobukola, Dairo and Odunewu, 2008), carrot (Doymaz, 2004), okra (Sobukola, 2009). Iciek and Krysiak (1995) studied the effect of various parameters of convective drying on the quality of Irish potatoes. In addition, several thin layer models have been proposed for explaining the drying behaviour of these agricultural products. These equations allow the prediction of the process parameter as a function of time at any point in the drying process based on the initial condition. These include models for: potato slices, yam (Akanbi, Gureje and Adeyemi, 1996), rice (Basunia and Abe, 1998), maize (Courtois et al., 1991; Falabella, Suarez and Viollaz, 1991), onions (Elustondo, Pelegrina and Urbicain, 1996; Faborode, Favier and Ajayi, 1995), plantain (Johnson, Brennan and Addo-Yobo, 1998), and apple (Chiang and Petersen, 1987). Diamante and Munro (1993) presented a model for the thin layer drying of sweet potato slices under solar conditions. Since the industrial production of food products normally depend on artificial dryers, there is a need to investigate the drying kinetics of sweet potatoes under artificial dryer conditions. Also, since pre-treatments are important in industrial drying, their effects need to be investigated. Singh et al., (2006) investigated the effect of air temperature and pretreatments on drying kinetics of sweet potato slices. The authors considered pre-treatments using potassium permanganate solution and citric acid and reported that the drying rate and therefore the drying constant values were found to be affected by the pretreatments. The objectives of this research were to determine the effect of temperature, and pre-treatment using hot water blanching and sodium meta-bisulphite on the drying kinetics of sweet potato slices in a convective air dryer.

2 Theorectical aspects

Drying is essentially a process of simultaneous heat and mass transfer (Dincer, 1998) and remains one of the most effective methods of preserving agricultural products. An understanding of the process is important because of the undesirable changes in the quality of dried products which may result if improperly implemented (Akpinar, Bicer and Midilli, 2003).

2.1 Mathematical model equations used for drying of agricultural products

A number of drying models have been reported in literature. Table 1 presents some of the mathematical models for thin layer drying of food materials.

Table 1 Mathematical models for drying characteristics of products

No.	Model name	Model equation	Reference
1	Newton	$MR=\exp(-kt)$	Mujumdar and Menon (1995)
2	Logarithmic	$MR=a\exp(-kt)+c$	Yagcioglu, Degirmencioglu and Cagatay (1999)
3	Henderson and Pabis	$MR=a\exp(-kt)+c$	Zhang and Litchfield (1991)
4	Modified Henderson and Pabis	$MR=a\exp(-kt)+b\exp(-gt)+c\exp(-ht)$	Gunhan et al., (2005)
5	Approximation of Diffusion	$MR=a\exp(-kt)+(1-a)\exp(-kbt)$	Yaldiz and Ertekin (2001)
6	Page	$MR=\exp(-kt^n)$	Diamante and Munro (1993)
7	Modified Page 1	$MR=a\exp(-(kt)^n)$	Akpinar, Bicer and Midilli, (2003)
8	Two Term Exponential	$MR=a\exp(-kt)+(1-a)\exp(-kat)$	Sharaf-Eideen, Blaisdell and Hamdy (1980)
9	Wang and Singh	$MR=1+at+bt^2$	Wang and Singh (1978)
10	Midilli Kucuk &Yapar	$MR=a\exp(-kt^n)+bt$	Midilli, Kucuk and Yapar, (2002)

Note: MR is dimensionless moisture ratio; a, b, k, t, n are coefficients.

Moisture ratio during drying experiment is usually calculated by using the following equation

$$MR = \frac{M_t - M_e}{M_o - M_e} \quad (1)$$

where, M_e is equilibrium moisture content, kg water/kg dry matter; M_o: initial moisture content (kg water/kg dry matter); M_t is moisture content at any time *t*, s.

The drying rate is calculated by using the following equation

$$D_R = \frac{M_{t+dt} - M_t}{D_t} \quad (2)$$

where, D_R is drying rate; M_t is as introduced earlier and M_{t+dt} is M_t after some incremental time d t; D_t is the elapsed drying time. Coefficient of determination (R^2) is the primary criterion for selecting the best equation to describe drying curve. Reduced chi square (χ^2) is the mean square of the deviation between the experimental and the predicted values for the models. The root mean square error (RMSE) is used to get the goodness of fit. The higher the values of R^2, the lower the value of x^2 and the *RMSE*, hence the better of the goodness of fit (Yaldiz and Ertekin, 2001; Akpinar, Bicer and Midilli, 2003; Gunhan et al., 2005). They are calculated as

$$R^2 = \frac{\sum_{i=1}^{n}\left(MR_i - MR_{pre,i}\right).\sum_{i=1}^{n}\left(MR_i - MR_{\exp,i}\right)}{\sqrt{\left[\sum_{i=1}^{n}\left(MR_i - MR_{pre,i}\right)^2\right]\left[\sum_{i=1}^{n}\left(MR_i - MR_{\exp,i}\right)^2\right]}} \quad (3)$$

$$\chi^2 = \frac{\sum_{i=1}^{n}\left(MR_{\exp,i} - MR_{pre,i}\right)^2}{N - z} \quad (4)$$

$$RMSE = \left[\frac{1}{z}\sum_{i=1}^{n}\left(MR_{pre,i} - MR_{\exp,i}\right)^2\right]^{\frac{1}{2}} \quad (5)$$

where, $MR_{exp,i}$ is the *ith* experimentally observed moisture ratio; $MR_{pre,i}$ is the i^{th} predicted moisture ratio; *N* is the number of the observation; *z* is the number of constant in the model; *n* is a positive integer.

2.2 Effective moisture diffusivity and activation energy

The effective moisture diffusivity is calculated by using the simplified Fick's second law of diffusion model:

$$\frac{\partial M}{\partial t} = D_{eff}\nabla^2 M \quad (6)$$

where, *M* is moisture content (kg water/kg dry matter); *t* is the time s; D_{eff} is the effective moisture diffusivity, m^2/s; ∇ is the differential operator. The solution of Fick's second law in slab geometry, with the assumption that moisture migration was caused by diffusion, negligible shrinkage, constant diffusion coefficient and temperature was given by Crank (1975) as follows:

$$MR = \frac{M_t - M_e}{M_o - M_e} = \frac{8}{\pi^2}\sum_{i=1}^{n}\frac{1}{(2n-1)^2}\exp\left(\frac{-(2n-1)^2\pi^2 D_{eff} t}{4H^2}\right) \quad (7)$$

where, *H* is the half thickness of the slab m; *n* = 1, 2, 3 … the number of terms taken into consideration. For long drying time Equation (7) can be simplified further (Lopez et al., 2000; Doymaz, 2004) as:

$$MR = \frac{8}{\pi^2}\exp\left(\frac{-\pi^2 D_{eff} t}{4H^2}\right) \quad (8)$$

Activation energy is obtained by plotting the natural logarithm of D_{eff} against the reciprocal absolute temperature. Lopez et al., (2000) and Simal et al., (1996) related temperature with Arrhenius expression as

$$D_{eff} = D_o \exp\left(\frac{-E_a}{R(T + 273.15)}\right) \quad (9)$$

where, D_o is the constant in Arrhenius equation, m^2/s; E_a is the activation energy (kJ/mol); *T* is the temperature of air, ℃; *R* is the universal gas constant, kJ/(mol·K).

Rearranging Equation (9) gives Equation (10):

$$\ln D_{eff} = \ln D_o - \frac{E_a}{R(T + 273.15)} \quad (10)$$

Energy of activation can thus be calculated from Equation (10), which gives a relationship between temperature and effective moisture diffusivity. The plot of ln*D* versus 1/(*T*+273.15) gives a straight line (slope of $K_L = E_a / R$). Linear regression analyses were used to fit the equation to the experimental data to obtain the coefficient of determination (R^2).

3 Materials and methods

3.1 Materials

Sweet potatoes tubers (*centennial* variety) were purchased from a local market in Ikorodu, Lagos Nigeria. They were thoroughly washed in clean, potable water. A sharp stainless steel knife was used to peel the sweet potato under water to prevent browning. The sweet potatoes were cut into slices perpendicular to the main axis of the whole tuber. The thickness of the slices was (4±0.02) mm but other dimensions in term of length and width were not kept constant for all the samples. Some samples were blanched in hot water at 100℃ for 2 min and were labelled as "WAT". Some samples were dipped into sodium meta-bisulphite of 0.01% concentration at 100℃ for 2 min (Tortoe et al., 2012) and were labelled as "SMB". Other samples were left untreated and were labelled as "UNT".

The drying behaviour was investigated in a convective hot air dryer (Model SAST 54, Jouan, France) at 50, 60, 70 and 80℃ air drying temperatures with the air velocity fixed at 1.25 m/s. Low temperatures could result in prolonged drying while temperatures higher than the range specified could affect the physico-chemical properties and nutritional quality of any product made from sweet potato slices (Maruf, Akter and Jong-Bang, 2010). The drying system was run for at least 30 min to obtain steady conditions before placing the samples in the oven in thin single layer. Changes in weight of the slices were monitored at 30 min interval for the first 2 h and at 60 min interval thereafter. Further drying was stopped when changes in the weight of the samples with successive weighing time was no longer significant. The drying tests were conducted in duplicate at each air temperature for all the samples. Both blanched and unblanched sweet potato slices were analyzed for moisture content during drying. The initial weight before drying and the weight during the process at various times were recorded through the use of an analytical weighing balance (SARTORIOUS-CP 22025, Germany). Some samples for each treatment were kept from the start of drying and at the end for the purpose of moisture content estimation. The moisture content of the samples was determined using gravimetric oven method at 150℃ for 5 h (AOAC, 1990).

3.2 Mathematical modelling and drying curves

The *MR* of the sweet potato slices during thin layer drying experiment was calculated by using Equation (3). Four of the popular thin layer drying models reported to have performed well for roots and tubers (Tunde-Akintunde and Afon, 2009; Mayor and Sereno, 2004), namely Modified Page 1, Approximation of Diffusion, Two Term Exponential and Wang and Singh were selected and fitted to the data. Regression analysis was performed using Data Fit (Oakdale Engineering, 2008). The primary criterion for selecting the best equation to describe the drying curve was coefficient of determination (R^2).

3.3 Determination of effective moisture diffusivity and activation energy

The effective moisture diffusivity of the samples was estimated by using the simplified mathematical Fick's second diffusion model (Equation 8). The activation energy of the samples was obtained by plotting the natural logarithm of D_{eff} against the reciprocal of absolute temperature, then determining the slope of the straight line by using Equation (10).

4 Results and discussion

The time to reach about 10% dry basis (d.b.) moisture content from the initial moisture content of about 294% (d.b.) was found to be between 300 min and 360 min. A relatively high drying rate was observed within the first 90 min of the drying time, but as drying progressed, the moisture ratio was observed to decrease non-linearly with the increase in drying time for all samples (as shown in Figure 1). The drying of sweet potato slices exhibited the characteristic moisture desorption behaviour noted for many tuber crops (Tunde-Akintunde and Afon, 2009), which has been explained to be due to various forms in which water is present in food products.

4.1 Effect of temperature and pre-treatments

It was observed that increase in drying temperature reduced the drying time and vice versa. As shown in Figure 2, the drying rate values (g water/100 g DM hr) are significantly higher at the higher temperature (80℃) than at the lower (50℃). Besides, no constant drying period was observed. These results are in agreement with earlier observations for various fruits, roots and vegetables (Kajuna et al, 2010, Tunde –Akintunde and

Afon, 2009; Sacilik, Keskin and Elicin, 2006, and Doymaz, 2005).

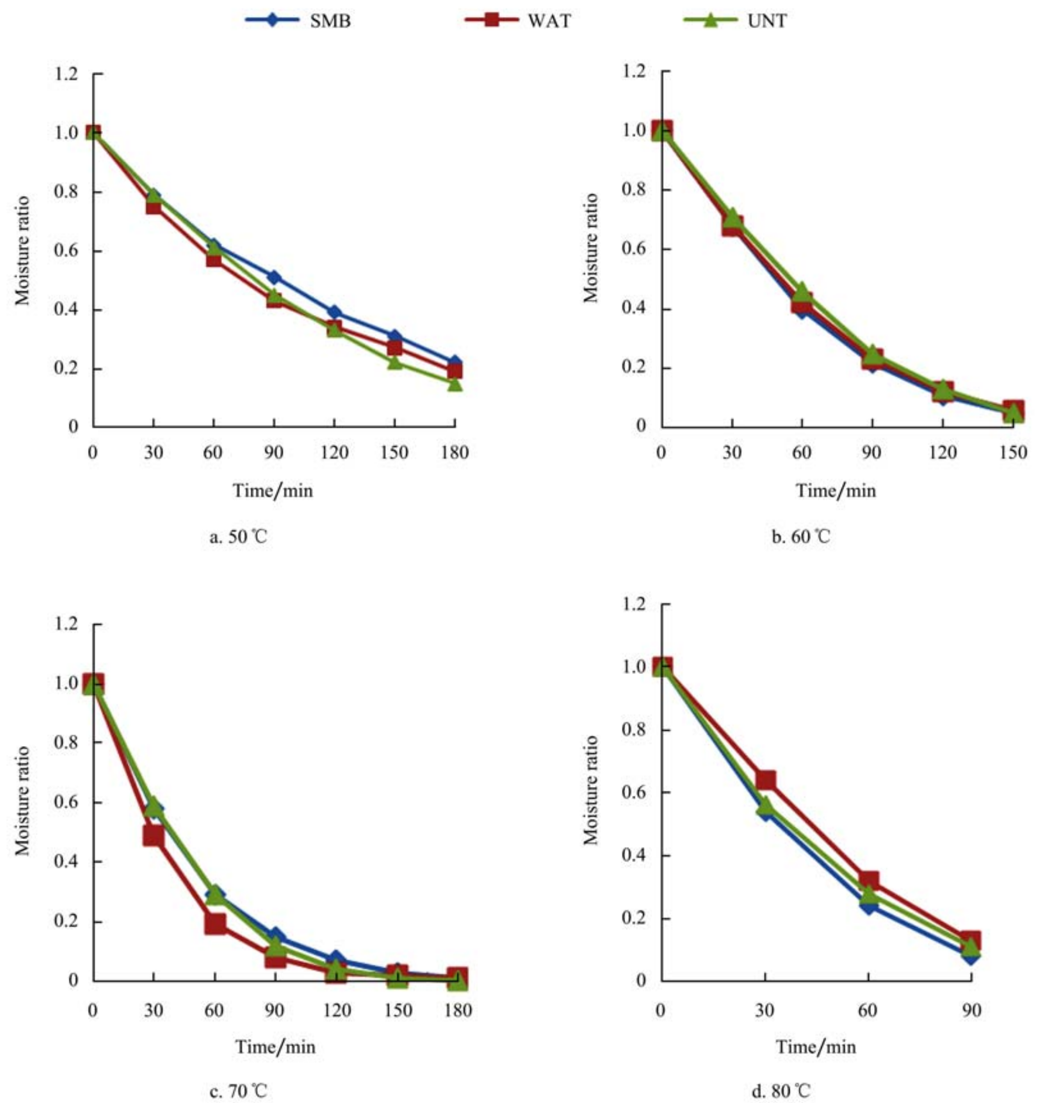

Figure 1 Drying curves for sweet potato slices at different drying temperatures

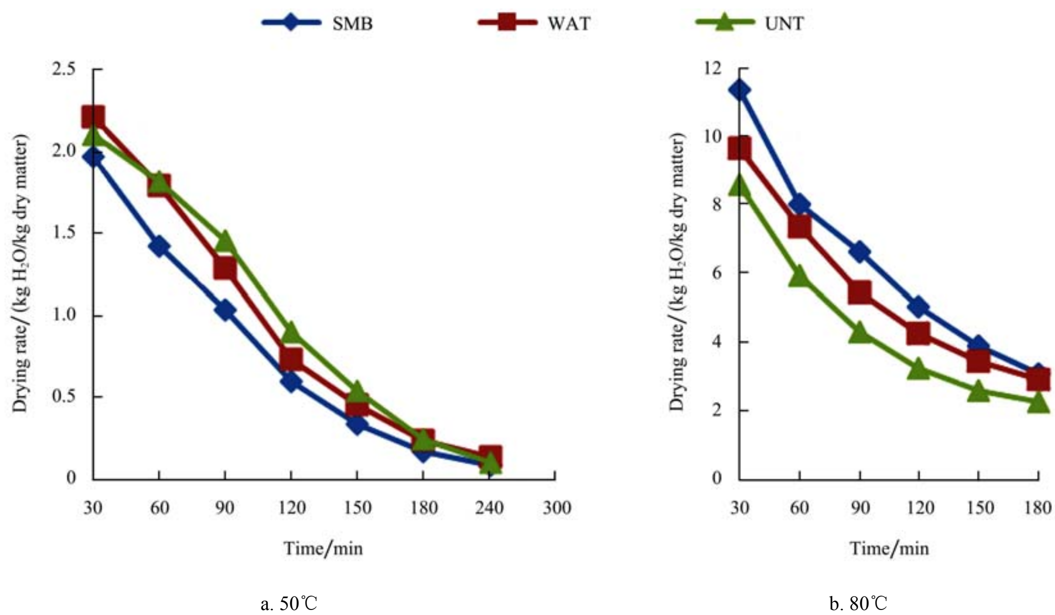

Figure 2 Drying rate curves for different pre-treatments

Figure 2 indicates that pre-treatments also affect the drying rate of sweet potato slices. At the lower temperature (50℃), the drying rate was only marginally different for the different pre-treatment schemes. At the higher temperature (80℃) however, the effects of the pre-treatment effects became more obvious, resulting in higher drying rates for both SMB and WAT. This shows that although pre-treatment reduces the resistance to moisture transport thereby increasing the drying rates, the effects are felt more at higher temperatures than at lower.

4.3 Mathematical modelling of drying of sweet potato slices

The result of the regression analysis performed to fit the experimental data to the selected thin layer drying models (Modified Page 1, Approximation of Diffusion, Two Term Exponential and Wang and Singh) are shown in Table 2. Based on the model with the highest R^2, the lowest χ^2 and lowest *RMSE*, the Page's model gave a better correlation between the moisture ratio and drying time of sweet potato slices under the conditions of the experiments.

Table 2 Regression analysis and fitting of experimental data to drying models

Model name	Treatment	Parameters	R^2	χ^2	*RMSE*
Modified Page 1	SMB at 50℃	a=0.989, k=5.832, n=0.573	0.99907	0.000183	0.0060618
	SMB at 60℃	a=0.999, k=7.784, n=1.266	0.99992	0.000062	0.0039545
	SMB at 70℃	a=0.999, k=9.901, n=1.175	0.99985	0.000119	0.0054586
	SMB at 80℃	a=0.995, k=9.934, n=1.142	0.99988	0.000367	0.0763802
	WAT at 50℃	a=0.991, k=4.656, n=1.064	0.99495	0.048582	0.3532192
	WAT at 60℃	a=0.998, k=7.567, n=1.252	0.99969	0.000242	.00779381
	WAT at 70℃	a=1.000, k=1.259, n=1.157	0.99970	0.000246	0.0078440
	WAT at 80℃	a=0.999, k=9.231, n=1.378	0.99847	0.002703	0.0130266
	UNT at 50℃	a=0.991, k=4.655, n=1.246	0.99907	0.002298	0.0295290
	UNT at 60℃	a=0.995, k=7.100, n=1.357	0.99879	0.000998	0.0157978
	UNT at 70℃	a=0.998, k=9.994, n=1.285	0.99978	0.000182	0.0067560
	UNT at 80℃	a=0.999, k=1.044, n=1.196	0.99964	0.000114	0.0030669
Approximation of Diffusion	SMB at 50℃	a=-7.497, b=0.971, k=1.707	0.99071	0.008785	0.03542602
	SMB at 60℃	a=-6.20, b=0.899, k=1.516	0.99986	0.000109	0.0052305
	SMB at 70℃	a=-6.984, b=0.928, k=1.70	0.99984	0.000129	0.0056923
	SMB at 80℃	a=-6.141, b=0.804, k=1.80	0.99796	0.001072	0.0165399
	WAT at 50℃	a=-4.445, b=0.936, k=6.62	0.99578	0.003777	0.0232922
	WAT at 60℃	a=-8.234, b=0.925, k=1.42	0.99965	0.000282	0.0084010
	WAT at 70℃	a=-6.908, b=0.229, k=0.22	0.99989	0.000088	0.0047094
	WAT at 80℃	a=-3.767, b=0.705, k=7.49	0.98970	0.004884	0.0506012
	UNT at 50℃	a=-4.864, b=0.885, k=8.87	0.99869	0.001315	0.0013710
	UNT at 60℃	a=6.149, b=0.885, k=0.014	0.99822	0.001465	0.0191376
	UNT at 70℃	a=-9.838, b=0.931, k=1.941	0.99966	0.000285	0.0084432
	UNT at 80℃	a=-6.132, b=0.461, k=1.309	0.99871	0.007548	0.0191065
Two Term Exponential	SMB at 50℃	a=3.305, k=1.258	0.98147	0.017524	0.0468033
	SMB at 60℃	a=2.575, k=3.137	0.98918	0.008737	0.0418023
	SMB at 70℃	a=4.721, k=2.025	0.99687	0.002513	0.0224231
	SMB at 80℃	a=4.062, k=1.162	0.99672	0.005980	0.0460179
	WAT at 50℃	a=2.691, k=2.914	0.99455	0.004878	0.0246948
	WAT at 60℃	a=4.987, k=2.603	0.98977	0.008143	0.0403579
	WAT at 70℃	a=4.129, k=2.021	0.99757	0.001974	0.0198708
	WAT at 80℃	a=2.055, k=2.347	0.98790	0.006539	0.0562635
	UNT at 50℃	a=2.127, k=3.500	0.98746	0.012626	0.0397277
	UNT at 60℃	a=2.941, k=3.576	0.98065	0.015951	0.0564820
	UNT at 70℃	a=4.527, k=2.335	0.99099	0.007628	0.0390593
	UNT at 80℃	a=2.655, k=2.347	0.99987	0.000934	0.0070977

Model name	Treatment	Parameters	R^2	χ^2	*RMSE*
Wang and Singh	SMB at 50℃	*a*=-3.147, *b*=2.572	0.99552	0.004238	0.0230176
	SMB at 60℃	*a*=-5.921, *b*=8.994	0.99870	0.001050	0.0144959
	SMB at 70℃	*a*=-6.938, *b*=1.187	0.98741	0.010096	0.0449376
	SMB at 80℃	*a*=-7.386, *b*=1.330	0.99977	0.000926	0.0018755
	WAT at 50℃	*a*=-0.004, *b*=3.451	0.98916	0.009699	0.0348203
	WAT at 60℃	*a*=-5.777, *b*=8.599	0.99884	0.000916	0.0013542
	WAT at 70℃	*a*=-7.894, *b*=1.479	0.96600	0.027651	0.0743653
	WAT at 80℃	*a*=-6.925, *b*=1.148	0.99859	0.006017	0.0875537
	UNT at 50℃	*a*=-3.599, *b*=3.363	0.99917	0.000835	0.0102215
	UNT at 60℃	*a*=-5.428, *b*=7.462	0.99955	0.000373	0.0086473
	UNT at 70℃	*a*=-7.079, *b*=1.221	0.99322	0.005744	0.0338963
	UNT at 80℃	*a*=-8.337, *b*=1.893	0.99887	0.007611	0.0831376

4.4 Effective moisture diffusivity

The effective moisture diffusivity of the samples obtained is shown in the Table 3. The effective moisture diffusivity (D_{eff}) for drying SMB, WAT and UNT samples ranged between 1.20×10^{-8} and 7.76×10^{-9} m^2/s. Similar result have been obtained for other agricultural crops like organic tomatoes: 2.56×10^{-9}–4.28×10^{-9} and 4.29×10^{-9}–6.28×10^{-9} m^2/s (Sacilik, Keskin and Elicin, 2006); yam slices: 7.62×10^{-8}–9.06×10^{-8} m^2/s (Sobukola, Dairo and Odunewu, 2008); okra: 1.125×10^{-9}–9.93×10^{-9} m^2/s and 1.165×10^{-8}–7.13×10^{-9} m^2/s for treated and untreated samples respectively (Sobukola, 2009). Thus the diffusivity values obtained from the experimental data fall within the (10^{-11}–10^{-6} m^2/s) range reported for most food products (Doymaz, 2007; Tunde-Akintunde, 2009).

Table 3 Effective moisture diffusivity for different pre-treatment methods at various drying temperatures

Pretreatment	Air temperature/℃	D_{eff}/m$^2\cdot$s^{-1}
SMB	50	3.63×10^{-9}
WAT	50	2.11×10^{-9}
UNT	50	7.08×10^{-8}
SMB	60	4.76×10^{-9}
WAT	60	4.76×10^{-9}
UNT	60	3.59×10^{-9}
SMB	70	7.76×10^{-9}
WAT	70	7.12×10^{-9}
UNT	70	7.73×10^{-9}
SMB	80	1.09×10^{-9}
WAT	80	6.40×10^{-9}
UNT	80	1.20×10^{-8}

Moisture diffusivity, which is related to the quantity of heat passing normally through a unit area per unit time, is also affected by drying temperatures, as increasing the air temperature resulted in higher effective moisture diffusivity as shown in Table 3. Thus, energy consumption is expected to decrease as temperature increases at constant air velocity. This result is similar to the findings of Kouchakzadeh (2010) for pistachios and Motevali et al., (2012) for jujube.

4.5 Activation energy

The influence of temperature on the effective diffusivity was obtained by plotting lnD_{eff} against () is as shown in Figure 3 for SMB, WAT and UNT samples. From the slope of the graph, the activation energy was observed to be 11.25 kJ/mol, 9.13 kJ/mol and 17.5 kJ/mol for treated SMB, WAT and UNT samples, respectively.

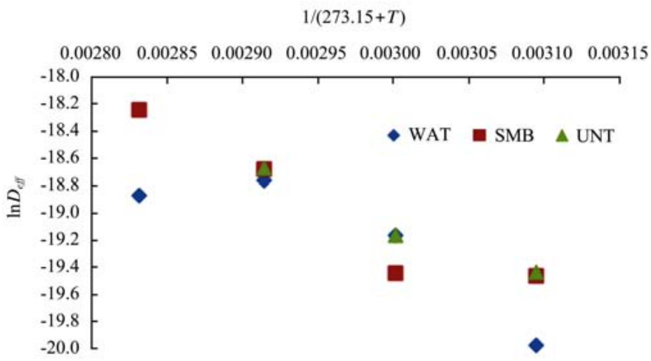

Figure 3 Influence of drying air temperature on effective diffusivity of sweet potato slices

The result of the activation energy was found to be 11.25 kJ/mol, 9.13 kJ/mol and 17.5 kJ/mol for treated SMB, WAT and UNT samples respectively. From the result, it was clearly observed that there was lower activation energy for the pre-treated samples (SMB and WAT) than for the untreated samples UNT. This indicates that it was easier to induce the water release process in the WAT and the SMB compared to the UNT samples. Similar results have been reported by Doymaz (2007).

5 Conclusions

This study evaluates the effects of pre-treatment on the drying characteristics of sweet potato slices. The experimental drying data were fitted to four well known drying models, includes the Modified Page 1, Wang and Singh, Two Term Exponential and Approximation of Diffusion. The following conclusions are drawn from the present study:

1) The drying of sweet potato slices exhibited higher drying rates for pre-treated samples than for untreated samples, especially at higher temperatures.

2) The R^2 *values for* Modified Page's model were higher and the χ^2 and RMSE values were lower than that from the other three models. Modified Page's model is therefore judged to have performed best in describing the drying curve of sweet potato slices under the considered experimental conditions.

3) The effective moisture diffusivity for SMB, WAT and UNT samples ranged between 0.12×10^{-9} and 7.76×10^{-9} m^2/s, increasing the air temperature resulted in the higher effective moisture diffusivity.

4) There was lower activation energy for the pretreated samples (SMB and WAT) than for the untreated samples UNT. The result of the activation energy was found to be 11.25 kJ/mol, 9.13 kJ/mol and 17.5 kJ/mol for treated SMB, WAT and UNT samples respectively. This indicates that it was easier to induce the water release process in the WAT and the SMB compared to the UNT samples.

References

Akanbi, C. T. , P. O. Gureje, and I. A. Adeyemi. 1996. Effect of heat-moisture pre-treatment on physical characteristics of dehydrated yam. *Journal of Food Engineering,* 28(1): 45-54. Elsevier Science Limited.

Akpinar, E. K., Y. Bicer, and A. Midilli. 2003. Modeling and experimental study on drying of apple slices in a convective cyclone dryer. *Journal of Food Process Engineering,* 26(6): 515–541.

AOAC. 1990. Official Method of Analysis. No. 934.06. Arlington: Association of Official Analytical Chemists.

Ayinde F. A., and R. R. Dinrifo. 2001. Effect of storage & pre-storage treatments on the quality of dried sweet potato slices. *Annals of Agricultural Sciences,* 22(1): 16-20.

Babajide, J. M., A.O. Obadina, O.B. Oyewole, and L.N. Ugbaka. 2006. Microbial quality of dry yam ''gbodo'' parboiled with/without adjuncts. *African Journal of Biotechnology,* 5: 278–281.

Basunia, M. A., and T. Abe. 1998. Thin-layer drying characteristics of rough rice at low and high temperatures. *Drying Technology*, 16(3–5): 579–595.

Chiang, W. C. and J. N. Petersen. 1987. Experimental measurement of temperature and moisture profiles during apple drying. *Drying Technology*, 5(1): 25–49.

Courtois, F., A. Lebert, A. Duquenoy, J. C. Lasseran, and J. J. Bimbenet. 1991. Modelling of drying in order to improve processing quality of maize. *Drying Technology*, 9(4): 927–945.

Crank, J. 1975. Mathematics of Diffusion, 2nd edition. London: Oxford University Press.

Diamante, L. M., and P. A. Munro. 1993. Mathematical modelling of the thin layer solar drying of sweet potato slices. *Solar Energy*, 51(4): 271–276.

Dincer, I. 1998. Moisture transfer analysis during drying of slab woods. *Heat and Mass Transfer,* 34(4): 317–320.

Doymaz, I. 2007. Air-drying characteristics of tomatoes. *Journal of Food Engineering,* 78(4): 1291–1297.

Doymaz, I. 2005. Sun drying of figs: an experimental study. *Journal of Food Engineering,* 71(4): 403–407.

Doymaz, I. 2004. Convective air drying characteristics of thin-layer carrots. *Journal of Food Engineering,* 61: 359–364.

Doymaz, I., and M. Pala. 2002. The effect of dipping pre-treatments on air-drying rates of the seedless grapes. *Journal of Food Engineering,* 52(4): 413-417.

Elustondo, M. P., A. H. Pelegrina, and M. J. Urbicain. 1996. A model for the dehydration rate of onions. *Journal of Food Engineering*, 29(3/4): 375–386.

Faborode, M. O., J. F. Favier, and O. A. Ajayi. 1995. On the effects of forced air drying on cocoa quality. *Journal of Food Engineering*, 25(4): 455–472.

Falabella, M. C., C. Suarez, and P. E. Viollaz. 1991. Drying kinetics of corn in contact with a solid adsorbent. *Journal of Food Engineering*, 13: 273–283.

FAO. 2008. United Nations, Food and Agriculture Organization Statistical Database. FAOStat (5/2008).

Franco, P., M. Pedro, S. Natalie, P. Romina. 2007. Physical properties of pre-treated potato chips. *Journal of Food Engineering,* 79: 1474–1482.

Gunhan, T., V. Demir, E. Hancioglu, and A. Hepbasli. 2005. Mathematical modeling of drying of bay leaves. *Energy Conversion and Management***,** 46: 1667–1679.

Iciek, J., and W. Krysiak. 1995. Convection drying conditions of potatoes and its effect on quality of dried material. In *Properties of water in foods*. *Proceedings of the Sixth Seminar*; Lewicki, P. P., Ed.; Warsaw Agricultural University Press: Warsaw, Poland. pp38−52.

Indrasari, S. D., B. A. Suismono, S. Susila, C. C. Wheatley, and G. Prain. 1994. The utilization of sweet potato flour in several snack food products. pp. 152−159. *In* Hendroatmodjo H.J, Y. Widodo, Sumarno, and B. Guritno (Eds.). *Research Accomplishment of Root Crops for Agricultural Development in Indonesia*. Research Institute for Legume and Tuber Crops, Malang, Indonesia.

Johnson, P. N. T., J. G. Brennan, and F. Y. Addo-Yobo. 1998. Air drying characteristics of plantain (Musa spp). *Journal of Food Engineering*, 37: 233–242.

Kajuna S., V. C. K. Silayo, A. Mkenda, and P. J. J. Makungu. 2000. Thin- layer drying of diced cassava roots. *African Journal of Science and Technology (AJST), Science and Engineering Series,* 2(2): 94-100

Kouchakzadeh, A. 2010. Moisture Diffusivity of Five Major Varieties of Iranian Pistachios. *American Journal of Food Tech.,* 6: 253-259.

Krokida, M. K., and Z. B. Moroulis. 2001. Structural properties of dehydrated products during drying. *International Journal of Food Science and Technology*, 36: 529-548.

Lopez, A., A. Iguaz, A. Esnoz, and P. Virseda. 2000. Thin layer drying behaviour of vegetable wastes from wholesale market. *Drying Technology,* 18 (4&5): 995–1006.

Maruf, A., M. S. Akter, and E. Jong-Bang. 2010. Peeling, drying temperatures, and sulphite-treatment affect physicochemical properties and nutritional quality of sweet potato flour. *Food Chemistry,* 121(1): 112-118.

Mayor, L., and A. M. Sereno. 2004. Modelling shrinkage during convective drying of food materials: a review. *Journal of Food Engineering,* 61 (3): 373–386.

Midilli, A., H. Kucuk, and Z. Yapar. 2002. A new model for single layer drying. *Drying Technology,* 20: 1503–1513.

Moreno-Perez, L. F., J. H. Gasson-Lara, and E. Ortega-Rivas. 1996. Effect of low temperature-long time blanching on quality of dried sweet potato. *Drying Technology,* 14(7&8): 1834–1857.

Motevali, A., A. Abbaszadeh, S. Minaei, M. H. Khoshtaghaza, and B. Ghobadian. 2012. Effective Moisture Diffusivity, Activation Energy and Energy Consumption in Thin-layer Drying of Jujube (*Zizyphus jujube* Mill) *J. Agr. Sci. Tech,* 14: 523-532.

Mujumdar, A. S., and A. S. Menon. 1995. Drying of solids: principles, classifications and selection of dryers. In: Mujumdar A.S. (ed.), *Handbook of Industrial Drying.* New York: Marcel Dekker, 1–40.

Oakdale. Engineering. 1995-2008. Data fit version 9.0.59. Oakdale, PA 15070. USA

Okaka J. C. 1997. Tropical plant perishables; Handling, storage and processing. Silicon Valey

Oyewole, O.B. 2002. The Powers at the Roots, Foods and Its Microbial Allies. UNAAB *Inaugural Lecture Serie*s No. 15, Abeokuta, Nigeria.

Sacilik, K., R. Keskin, and A. K. Elicin. 2006. Mathematical modeling of solar tunnel drying of thin layer organic tomato. *Journal of Food Engineering,* 73(3): 231–238.

Sharaf-Eldeen Y.I., J. L. Blaisdell, and M.Y. Hamdy. 1980. A model for ear corn drying. *Transactions of the ASAE,* 23(5): 1261–1271.

Senadeera, W., B. Bhandari, G. Young, and B. Wijesinghe. 2000. Physical property changes of fruits and vegetables during hot air drying. *Drying Technology in Agriculture and Food Sciences* (edited by A.S. Mujumdar), :159–161. Enfield Science Publishers.

Simal, S., A. Mulet, J. Tarrazo, and C. Rossello. 1996. Drying models for green Peas. *Food Chemistry*, 55(2): 121-128.

Singh, S., C. S. Raina, A. S. Bawa, and D. C. Saxena. 2006. Effect of Pretreatments on Drying and Rehydration Kinetics and Color of Sweet Potato Slices. *Drying Technology*, 24: 1487-1494.

Sobukola, O. P. 2009. Effects of Pre-Treatment on the drying Characteristics and Kinetics of Okra. *International Journal Food Science and Technology,* 41: 6-19.

Sobukola, O.P., O.U. Dairo, and V.O. Odunewu. 2008. Convective hot air drying of blanched yam slices. *International Journal Food Science and Technology*, 43: 1233-1238.

Tunde-Akintunde, T. Y., A. A. Afon. 2009. Modelling of Hot-Air Drying of Pre-treated Cassava Chips. *Agricultural Engineering International. The CIGR E-journal manuscript* 1493.

Tortoe, C., P-N. T. Johnson, L. Abbey, E. Baidoo, D. Anang, S. Acquaah, and E. Saka. 2012. *African Journal of Food Science and Technology* 3: 59-65.

Wang, C.Y., and R. P. Singh. 1978. A single layer drying equation for rough rice. ASAE Paper No. 783001. St Joseph, MI: ASAE

Woolfe, A. J. 1992. Sweet Potato: An Untapped Food Source: Cambridge University Press, Cambridge U.K. : 1 – 39.

Yagcioglu, A., A. Degirmencioglu, and F. Cagatay. 1999. Drying characteristics of laurel leaves under different drying conditions. In: *Proceedings of the 7th International Congress on Agricultural Mechanization and Energy*, Adana, Turkey

Yaldiz, O. and C. Ertekin. 2001. Thin layer solar drying of some different vegetables. *Drying Technology*, 19(2): 583–596.

Zhang, Q., and J. B. Litchfield. 1991. An optimization of intermittent corn drying in a laboratory scale thin layer dryer. *Drying Technology,* 9(2): 383–395.

Zuraida, N. 2003. Sweet Potato as an Alternative Food Supplement During Rice Shortage *Jurnal Litbang Pertanian,* 22(4): 150-155.