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Drying And Quality Characteristics of Pretreated Guava (*Psidium guajava*) SLICES

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ABSTRACT
Guava (Psidium guajava Linn.) is a sweet and highly nutritious fruits, which is high in minerals and vitamins especially vitamin C , needs preserved immediately after harvest. Drying has been one of the effective methods of preserving fruits and vegetables by reduction in moisture present to a level at which biochemical activities are hindered. Osmotic pretreatment reduces initial moisture and enhance retention of nutrients and physico-chemical qualities of the products.Thisresearch was therefore designed to study drying and quality characteristics of p.guajava. The slices were spitted in three parts, two parts pretreated separately in sucrose and maltodextrin solutions (1:10 w/v) for 1 h while control was untreated. All the pretreatment slices. Rehydration ratio (RR), effective moisture diffusivity (D_{eff}) and activation energy (E_a) were determined. Quality parameters such as ascorbic acid, lycopene, calcium, potassium, tannin, colour, water absorption capacity, bulk density (BD) and tapped density (TD) were determined using standard procedures. Three criteria namely: coefficient of determination (R^2),chi-square(χ^2) values and Root Mean Square Error (RMSE) were used to select the best among the chosen models using SPSS version 25. Rehydration ratio (RR) values ranged from (2.31-2.51), (2.35-2.54), and (2.14-2.38) for sucrose, maltodextrin pretreated and control samples respectively. The D_{eff}values of sucrose, maltodextrin pretreated and control p.guajavasamples at 50, 60 and 70°C ranged from(1.19×10^{-9} - $3.141\times 10^{-9} m^2/s$). The activation energies of the samples were 22.53, 29.88 and 49.83 kJ/mol. K for sucrose; Maltodextrin pretreated and control samples respectively. . The Modified Henderson and Pabis model was found to be best fit for the slices due to highest values of R^2 ,lowest χ^2 and RMSE values being 0.999,9.31E-05,0.0014737 and -0.00246 correspondinly for sucrose ,maltodextrin and control respectively at all temperatures. The values of water absorption capacity (WAC), bulk density (BD) rehydration ratio (RR) and tapped density (TD) ranged from (183-184), for sucrose pretreated samples, ranged (126 - 129) for maltodextrin pretreated samples (184-180) for control, bulk density ranged from (0.98-0.89), (0.77-0.82),(0.68-0.79) for sucrose, maltodexrin pretreated and control sample respectively. RR values ranged from(2.31-2.51), (2.35-2.54), and (2.14-2.38) for sucrose, maltodextrin pretreated and control samples respectively.TD ranged from (0.57-0.67), (0.53-0.64) and (0.52-0.62) for sucrose, maltodextrin pretreated and control samples respectively. The values of colour change (ΔE), decreases as drying time increases, the values of L^*, a^*, and b^* for the samples were 56.04, 52.01 and 51.34, respectively.This research showed that drying at 70 °C retained the nutritional attributes of the samples evaluated. The Modified Henderson and Pabis gave the best model that best fits the drying process, while sucrose pretreated samples minimized nutrient loss. Thus, adoption of this method could help local farmers and food processor produce quality and shelf-stable products.
Keywords: *Guava (Psidium guajava Linn.) ,Drying, Quality Characteristics, Pretreated Guava, Slice.*

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I. Introduction

Guava (*Psidium guajava* Linn.) popularly known as poor man's apple in the tropics belongs to the family *Myrtaceae.* Itis a commercial fruit of tropical and sub-tropical region (Tripathy *et al.,* 2016).The entire guava tree has potential therapeutic effects and are used as folk medicine in many parts of the globe *Psidium guajava* has nearly six times the vitamin C content of an orange, making it an extremely nutritious fruit (Singh and Tiwari, 2019). *Psidium guajava* is very nutritious and one of the sweetest fruits in the world which is high in fiber and a good source of essential vitamins and minerals (Vijaya *et al.,* 2020).*P. guajava*, as a climacteric fruit, exhibits a fast increase in respiration and ethylene production during ripening. At room temperature, *Psidium guajava* flesh has a shelf life of 2 to 4 days (Yadav *et al*., 2022).

Several postharvest handling methods, including controlled/modified atmosphere and cold storage, have been suggested to prolong storage life and maintain guava fruit quality. *Psidium guajava* fruit's export potential is limited due to its delicate character, brief post-harvest life, and susceptibility to chilling injury and diseases (Deepthi *et al* 2017). Osmotic dehydration is a pre-treatment technique widely used in fruit processing to reduce water content before drying, which enhances product quality, improves the efficiency of subsequent drying methods such as convective air drying, freeze drying by reducing drying time and minimizing thermal degradation (Panagiotou*et al*.,2016). Osmotic dehydration has been found effective in preserving bioactive compounds like vitamin C and phenolic which are sensitive to heat. Osmotically hydrated *Psidium guajava* retains more nutrients and colour when compared to dried samples (Sarga*et al*., 2010). Osmotic agents such as temperature, immersed time, and fruit- to-solution are important parameters that influence mass transfer kinetics and product quality.

Food preservation by drying is a time-honored and widely used technique by humanity and the food processing industry. Food dehydration is one of the most significant accomplishments in human history, reducing our species reliance on a daily food supply even in adverse environmental conditions. Previously, drying was done in the sun, but today a variety of sophisticated tools and techniques are used to dehydrate foods. Significant efforts have been made in recent decades to understand some of the chemical and biochemical changes that occur during dehydration and to develop methods to avoid undesirable quality losses. Among the numerous methods used for food conservation, drying is unquestionably the most ancient but still very much used nowadays. It is a process by which water is removed from the food, by vaporization or sublimation, thus reducing the water available for degradation reactions of chemical, enzymatic or microbial nature. The drying rate is influenced by transfer mechanisms, such as the vapour pressures of the food and of the drying air, temperature and air velocity, Moisture diffusion in the product, thickness and surface exposed for drying,Lerici*et .al., (*2015).

II. MATERIALS AND METHODS

2.1 Materials Used

Freshly harvested matured pink *Psidium guajava* samples at physiological stage seven of maturity in very good conditions were purchased from a commercial fruit market at Arada in Ogbomoso, Oyo State, Nigeria. The fruits were taken to the Department of Crop Production and Soil Science of Ladoke Akintola University of Technology (LAUTECH),Ogbomoso, Nigeria for identification. The fruit were thereafter sorted, graded for uniform size and transferred to pre-cooled at temperature 25°C for 6 hours to remove field heat.

2.2 Theoretical Considerations

The drying characteristics of the samples were calculated based on the data derived from the drying period and the drying temperature on the moisture content of the guava slices.

2.3 Effective moisture diffusivity (D_{eff})

According to Workneh and Oke (2013), the drying characteristics of biological products are in the falling rate period and described Fick's diffusion equation. The Fick's equation is given as:

$$J = D * (dc / dx) \quad (1)$$

where: J is the diffusion flux (among of substance diffused per unit area per unit time), t is time, D is the diffusion coefficient, dc / dx is the concentration gradient (change in concentration over distance). This equation states that the rate of change of concentration (dC/dt) is proportional to the place operator (V^2C), which represents the spatial distribution of the concentration. The constant of proportionality is the diffusion coefficient (D).

Although the diffusivity equation is not the best equation to fit experimental data. However, it provides an approximate method to present a common quantitative comparison between different products. It can also provide a description for average diffusion coefficient in the entire drying process. The solution to this equation developed by Crank (1975) can be used for various regularly shaped bodies such as slab, cylindrical, and spherical shapes. For long drying period, this solution can be written in a logarithmic form as follows, Abioye*et.al*, (2018)

$$MR = \frac{(M-M_e)}{(M_o-M_e)} = \frac{8}{\pi^2}\exp\left(\frac{-\pi^2 D_{eff}}{4{L_0}^2}t\right) \quad (2)$$

Where, D_{eff} = the effective moisture diffusivity (m^2/s), t = the drying time (s) and L_o= the half thickness of the samples (m). Equation (3) in linearised by taking the nature logarithms of the both sides as thus:

$$\ln(MR) = \frac{-\pi^2 D_{eff}}{4{L_0}^2}t + ln\frac{8}{\pi^2} \quad (3)$$

The experimental drying data were plotted in terms of In (MR) against time at different temperatures. The slope derived from the linear regression of the graphs was used to calculate the effective moisture diffusivity as:

$$\text{Slope} = \frac{-\pi^2 D_{eff}}{4{L_0}^2} \quad (4)$$

2.4 Determination of activation energy (E_a)

The dependence of the effective diffusivity on the drying temperatures can be predicted appropriately using the Arrhenius equation which is given by Abioye*et al.* (2021) and Workneh and Oke (2013):

$$D_{eff} = D_o\exp\left(-\frac{E_a}{R(T+273.15)}\right) \quad (5)$$

where, $D_{eff}$is the effective moisture diffusivity in m^2/s, D_o is the pre-exponential factor of Arrhenius equation or maximum diffusion coefficient (at infinite temperature) in m^2/s, $E_a$is the activation energy in KJ/mol, R is the universal gas constant in KJ/ mol K and T is temperature in ºC Linearizing the equation gives:

$$In\,D_{Deff} = In\,D_0 - \frac{E_0}{R_g} - \frac{1}{T} \quad (6)$$

The activation energy $E_a$was obtained by plotting natural logarithm of effective diffusivity with reciprocal of absolute temperature.

2.5 Determination of Quality Attributes of *Psisium guajava* Samples

The following quality parameters of the *Psidium guajava* samples were determined, in triplicates unless otherwise stated: The

The rehydration ratio of the dehydrated products was determined according to the method described by Srivastava and Kumar (2012). The dehydrated samples of 5 g each were placed in a glass beaker, 100 ml of water was added and heated at 40-45 ºC for 60 min. The excess water was drained off through blotting paper. The drained samples were weighed. Rehydration ratio (RR) and moisture content (MC) in the dehydrated samples were computed using the equation below:

$$\text{Rehydration ratio } RR = \frac{c}{d} \quad (7)$$

where; c = drained weight of rehydrated samples and d = weight of dehydrated samples taken for rehydration test. Tannin was Estimation of tannin

2.6 Statistical Analysis and Mathematical Modelling of Dried *Psidiumguajava* Powder

The experimental data of moisture ratio versus drying time were fitted to six thin–layer models, which are widely used in the scientific literature to describe the kinetics of the drying process, Hussein *et al.,* 2016; Tunde-Akintunde and Oke, 2012; Workneh and Oke, (2013). The quality parameters of the dried guava powder were statistically analyzed using Statistical Package for Social Scientists (SPSS) 25 software package and were also subjected to analysis of variance (ANOVA). The thin-layer drying models used include Henderson and Pabis, Modified Henderson and Pabis, Logarithmic, Page, Midilli-Kucuk, and Parabolic models. Several researchers had recommended the above models as best fit models for thin layer drying fruits and vegetables, Hussein *et al.*, 2016; Tunde-Akintunde and Oke, (2012).

A non-linear regression procedure for the six models was carried out using Statistical Package for Social Sciences (SPSS) 25 software package. The criteria used for selecting the best model to define the drying curves are the Coefficient of Determination (R^2), Chi-square (χ^2), Root Mean Square Error (RMSE) and Mean Bias Error (MBE) which are calculated from Equations 1 - 8. The criteria were used to determine the extent quality of the fit of the models. The drying model with highest value of R^2 and the lowest values of χ^2, RMSE and MBE was chosen as the best model describing the thin layer drying characteristics of pretreated guava slices. This is because the higher the values of R^2, and the lower the values of χ^2, RMSE and MBE, the better the goodness of fit (Doymaz, 2011; Hu *et al.*, 2016).

III. Results and Discussion

3.1 Effect of Temperature and Pretreatment on the Drying Characteristic of *Psidium guajava*

The curves of moisture content againstdrying time of *Psidium guajava* slices with different pretreatments. Sucrose and maltodextrin pretreated samples had a lower drying rate and a longer drying time while the control sample had the highest drying rate and the shortest drying time (Table 1). The osmo-pretreatments (sucrose and maltodextrin) will expectedly gave rise to significant dry matter content of the slices before drying probably due to solute impregnation during pre-treatments. The presence of solute in *Psidiumguajava* slices would create hydrogen bonds with free water molecules. This could cause internal and external diffusion resistance, leading to limited moisture removal from the slices in the drying process,Goula and Adamopoulos, (2008); Nguyen *et al*., (2023).

Table 1: Final moisture content and total drying time of pretreated *Psidium guajava* slices dried with different drying treatments.

Pretreatment	Treatment	Total drying time	Final m.cw.b%
	Fresh	___	82.50±0
Sucrose Solution	50 ºC	15±0.3h	8.072±0.2
	60 ºC	15±0.4h	9.84±0.02
	70 ºC	18±0.4h	9.92±0.01
M.D. Solution	50 ºC	13±0.3h	8.065±0.1
	60 ºC	10±0.4h	9.45±0.1
	70 ºC	14±0.3h	9.35±0.0
Control	50 ºC	6±0.4h	10.02±0.2
	60 ºC	7±0.5h	9.71±0.2
	70 ºC	8±0.4h	9.65±0.3

3.2 Effects of Temperature and Pretreatment on Drying Rate of Dried *Psidiumguajava*

The effects of temperature on the convective drying kinetics of *Psidium guajava*slices . The drying rates of the pretreated dried samples were observed to be higher than of the control samples in the two drying treatments. This shows that the pretreatments used on the samples prior to drying is highly significant. However, it was revealed that the moisture content of the samples decreases as the drying rate increases.

3.3 Effects of Pretreatments and Temperature on Moisture Diffusivity of Pretreated Dried *Psidium guajava* slices.

The moisture diffusivity was measured using established techniques, by plotting a graph of in MR (moisture ratio) against drying time and the results were analyzed to assess the impact of the pretreatments on the drying process. The values of effective moisture diffusivity were calculated using Equation 3.7and are shown in Figures 1. The evaluated values of D_{eff} of sucrose pretreated samples varied from $1.198\text{x}10^{-9}m^2/s$ to $1.946\text{x}10^{-9} m^2/s$, and for maltodextrin pretreated samples varied from $1.069\text{x}10^{-9}m^2/s$ to $2.351\text{x}10^{-9}m^2/s$ while the control samples varied from$1.069\text{x}10^{-9}m^2/s$ to $3.141\text{x}10^{-9} m^2/s$. It was observed from the results that moisture diffusivity increases with increase in temperature.

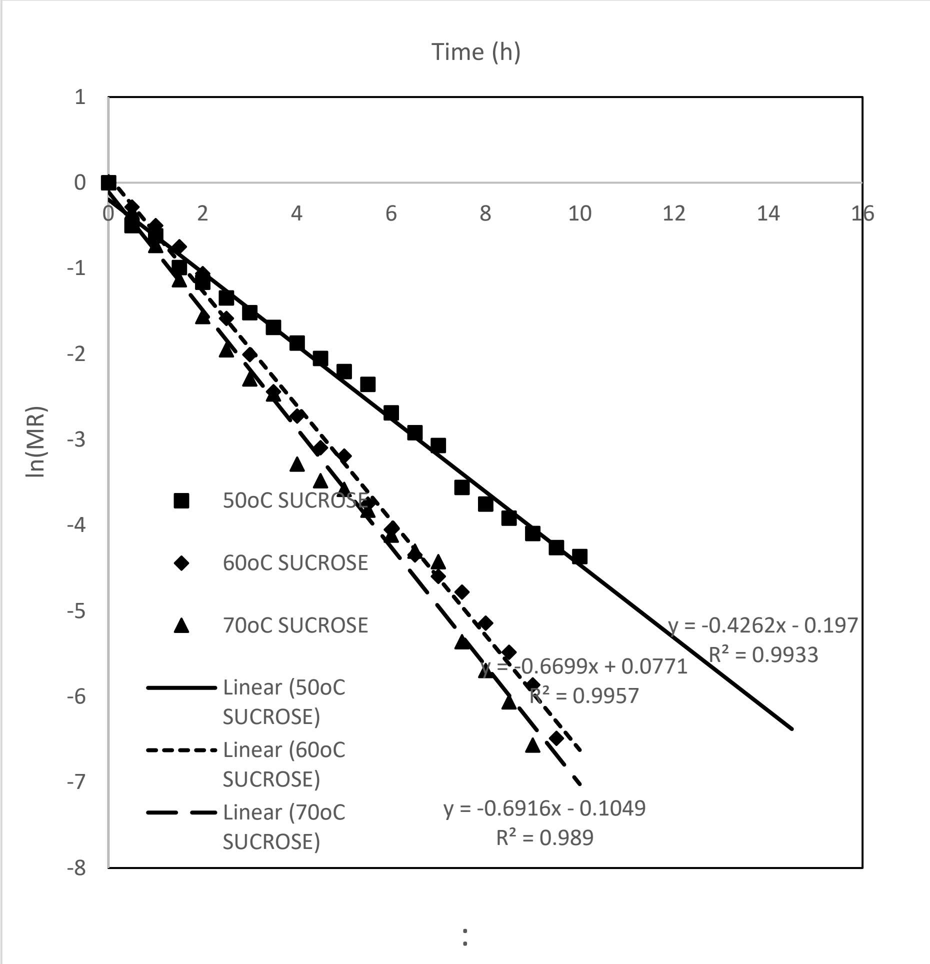

Figure 1: Evaluation of effective moisture diffusivities for sucrose pretreated *Psidium guajava* slices at different drying temperatures

3.4 Effect of Temperatures on Activation Energy of *Psidium guajava*Samples

Temperature is an important factor influencing the kinetics of various processes in the drying of fruits. The activation energies of the drying experiment were derived from the slope of plot of the calculated logarithmic natural effective moisture diffusities ($\ln D_{eff}$) against the inverse of the absolute temperature ($1/T_{ab}$). The results obtained were 27.09, 39.95 and 59.94 kJ/mol for *Psidium guajava*. Samples dried at 50, 60 and 70 ºC. These results were in line with activation energy obtained by Wokneh and Oke (2013). Table 4.4: Selected chemical Characteristics of oven-air dried pretreated *Psidum guajava*slices at different temperature

Pretreatment	Temperature (ºC)	Lycopene (mg/100 g)	Calcium (mg/100 g)	Potassium (mg/100 g)	Tannin (mg/100 g)
	50	229.15±4.33[b]	29.88±0.02[c]	111.34±8.33[b]	3.43±0.12[a]
Sucrose	60	227.96±3.05[b]	28.29±0.62[c]	110.34±8.33[b]	3.45±0.04[a]
	70	227.76±4.41[b]	27.29±0.67[c]	105.8±1.29[b]	3.52±0.01[a]
	50	239.26±4.77[b]	21.93±0.77[b]	114.50±10.60[b]	8.94±0.49[c]
Maltodextrin	60	238.12±3.17[b]	20.93±0.76[a]	113.50±10.60[b]	8.91±0.00[c]
	70	237.12±8.82[b]	20.43±0.06[a]	109.0±2.83[b]	8.98±0.01[c]
	50	104.52±3.84[a]	21.75±1.13[b]	97.79±3.42[a]	6.53±0.07[b]
Control	60	102.52±3.84[a]	20.75±1.13[a]	96.79±3.42[a]	6.39±0.06[b]
	70	99.84±8.82[a]	20.23±0.99[a]	98.8±0.63[a]	6.42±0.02[b]

Mean within the same column with different alphabets(s) are significant different at $p<0.05$

M.D: maltodextrin, P.T: pretreatment, MC: Moisture Content, Water Absorption Capacity, RR: rehydration ratio, BD: Bulk Density, TD: taped density

3.5 Effect of Temperature on Retention of Colour of Pretreated *Psidium guajava*Samples.

The visual appeal of food samples after drying conditions has to do with its pigment, which will enable its acceptability in the market to the final consumers. According to Workeh and Oke (2013), the changes in colour of the dried pretreated *Psidium guajava* samples, it indicate each values of L*, a* b* and ΔE which demotes lightness, redness and yellowness. The values of 50, 60, and 70ºc for sucrose pretreated samples were 44.22,43.22 and 42.72. Also for maltodextrin pretreated samples, values at 50, 60 and 70ºC were 40.16, 39.16, 38.72 respectively. The control samples values at 50, 60 and 70ºCwere 37.21, 36.16 and 34.66. these result. The best colour retention was shown on sucrose pretreated *Psidium guajava* followed by maltodextrin pretreated samples and control samples. The lightness (L) decreases as the temperature increases from 50 to 70 ºC. The variation in the colour may be due to the effect of heat treatment which can affect its colour stability and enzyme activity. This observation was in agreement with Barman and Badwaik (2017). L. S. *et al.,* (2017)

3.6 Evaluation of Dry Models for Selected Pre-treated Guava Slices

The statistical modeling revealed the results that best fits the six thin-layer drying models, such as Henderson and Pabis, Modified Henderson and Pabis, Logarithmic, Page, MidilliKucuk, and Parabolic. The criteria used for he best model to

Pretreatment	Drying Temperature (ºC)	L*	a*	b*	ΔE
	50	44.22± 0.50^{b}	44.22±0.50^{b}	44.22±0.50^{b}	14.32±1.80^{a}
Sucrose	60	43.22±0.7^{b}	4.79±0.21^{a}	9.4±0.92^{a}	29.53±0.69^{a}
	70	42.72±0.04^{b}	5.94±0.02^{a}	13.94±0.1^{a}	30.34±1.00^{b}
	50	40.16±0.39^{b}	40.16±0.39^{a}	40.16±0.39^{a}	13.85±0.99^{b}
Maltodextrin	60	39.16±0.55^{b}	3.22±0.22^{a}	11.55±0.71^{a}	24.68±1.02^{b}
	70	38.72±0.01^{b}	3.72±0.69^{a}	9.54±0.56^{b}	23.04±1.68^{b}
	50	37.21±0.64^{a}	37.21±0.64^{a}	37.21±0.64^{a}	12.75±1.85^{a}
Control	60	36.16±0.60^{a}	2.52±0.6^{a}	8.22±0.78^{a}	21.05±1.22^{b}

IV. Conclusions

The study on the drying and quality characteristics of pretreated Psidium guajava samples exhibit enhanced drying characteristics compared to untreated samples. Sucrose pretreated samples facilities initial moisture removal, which accelerates the drying rate and reduces total drying time. Drying occurs in the falling rate period, indicating moisture diffusion as the main mechanism. As temperature increases from 50ºc to 70ºc drying rate increases, reducing drying time, Effective moisture diffusivity improves setter drying efficiency and enhances rehydration properties at dried guava slices.

Treated guava slices show better rehydration capacity, antioxidant activity and organoleptic qualities.Compared to untreated samples. Osmotic pretreatment particularly with sucrose enhances the physical, nutritional and functional qualities of guava slices, making it more suitable for food and nutraceutical application

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