Osmotic Dehydration Kinetics of Plantain (Musa paradisiaca) using a Low-calorie Sugar

Lobe Elias Eyembe
University of Bamenda
Divine Bup Nde (divinende@lsu.edu)
University of Bamenda
Jean Sonchieu
University of Bamenda

Research Article

Keywords: Osmotic dehydration, modeling, Water loss, Solid gain, Musa paradisiaca

Posted Date: January 25th, 2024

DOI: https://doi.org/10.21203/rs.3.rs-3841358/v1

Additional Declarations: No competing interests reported.

Osmotic Dehydration Kinetics of Plantain (*Musa paradisiaca*) using a Low-calorie Sugar

Lobe Elias Eyembe[12], Divine Bup Nde[1]*, Sonchieu Jean[3]

[1] Department of Nutrition, Food and Bio-resource Technology, College of Technology, University of Bamenda, Cameroon

[2]Department of Food Technology, National Polytechnic University Institute (NPUI), Mile 7 Nkwen, Bamenda, Cameroon. lobeeyembe@gmail.com

[3]Department of Social Economy and Family Management, Higher technical Teachers Training College, University of Bamenda, Cameroon

*Corresponding author present address: Department of Chemistry, Louisiana State University, divinende@lsu.edu; divinende@gmail.com

Abstract

Plantain is consumed as a stable food in most sub-Saharan countries and to some extent in southern America and Asia. To avoid deterioration of the plantain after harvest and to provide food variety, a reasonable quantity of plantain is now being transformed into flour. Osmotic dehydration (OD) is a critical step in the flour production process because it enhances the nutritional and sensory quality of the flour. There are concerns to use alternative osmotic agents to sucrose and salts to avoid their high content in the final product which have an adverse effect on the health of consumers. Suitable alternatives are low-calorie sugars (LCS) because they have low glycemic indices but which unfortunately have not been tested for the OD of plantain. The aim of this work was to study the osmotic dehydration of unripe plantain using a commonly consumed commercial LCS (Sussli) as an osmotic agent. The influence of process variables (thickness, concentration, sample/solution ratio and temperature) on mass transfer parameters; water loss (WL) and solute gain (SG) on osmotic dehydration of plantain (*Musa paradisiaca*) were evaluated. All parameters studied had a significant influence on weight loss and solid gain. The kinetics of the osmotic dehydration was modeled using the Azuara, Peleg and Page models. Plantain slice of thickness 5 mm, LCS solution concentration of 50 % at ambient temperature (25±2 °C), and a sample/solution ratio of 1:10 (w/v) was judged best for osmotic treatment of plantains in LCS. Under these conditions the weight loss and solid gain were 20 % and 1.73 % respectively. The Peleg model best described the dehydration kinetics with the highest R^2 (0.999) and the least RMSE.

Key words: Osmotic dehydration, modeling, Water loss, Solid gain, *Musa paradisiaca*

1. Introduction

Plantain (*Musa paradisiaca*) is an important dietary source of carbohydrate (31 g/100 g) in the humid tropical zones of Africa, Asia and South America [1] and an important staple food in Central and West Africa [2]. It is one of the most important sources of food energy in West and Central Africa, where about 70 million people obtain more than 25% of their carbohydrates [3]. The total annual world production is estimated to be over 76 million metric tons [4] with about 33 million metric tons produced in Africa [5]. Cameroon is ranked fourth in West and Central Africa with an estimated annual production rate of about 4.4 million metric tons [6]. In West and Central Africa, plantain plays an important role as a food security source with a consumption rate of 150 kg/capita/year [3]. The main forms of consumption include boiled, fried (chips), roasted, and pounded to form a mash (fufu) [3, 7]. A non-negligible part of the plantain is being transformed into flour for various uses in cooking, and in baking and confectionaries. Plantain processing to flour creates significant added value for stakeholders as it increases shelf life and ensures food security, because of its potential for use to produce diverse food products.

In recent years, a considerable amount of attention has been paid to the osmotic dehydration (OD) technique for the preservation of fruits and vegetables due to its potential to maintain sensory and nutritional properties close to fresh ones [8]. In OD, the potential difference between the osmotic pressure of fresh material and the surrounding solution provides a driving force for the withdrawal of water from cells into the solution [9]. Mass transfer during the osmotic process consists of two major simultaneous counter-current flows of water and solutes. There is also a negligible amount of flow of natural solutes present in the cells into the osmotic solution [10]. Mass transfer during osmotic dehydration is significantly influenced by solution concentration, temperature, immersion time, sample thickness and shape, solution-to-sample ratio, and applied pretreatments [11, 12].

Studies have been reported on the use of sucrose as an osmotic agent for the osmotic dehydration of carrot eggplant and beetroot [13]**,** Litchi [14]), kiwifruit) [15]. The increasing interest in designing new low-calorie and minimally processed foods [16], the replacement of conventional sugars in traditionally processed products as well as studies employing the use of alternative osmotic agents is continuously gaining interest [17]. This is because of the belief that the consumption of foods with regular sugar is thought to be the origin of several life-threatening ailments such as diabetes, hypertension, and coronary diseases [18, 19]. It is therefore important to find new alternatives to sucrose solutions, which can be used in osmotic dehydration processes to limit some of these adverse health effects.

The osmotic dehydration of ripe plantain using sucrose as the osmotic agent has been reported by several researchers [20-23]. The resulting product may not be good for consumption by people with certain ailments especially diabetics because the use of sucrose coupled with the high sugar content of ripe plantain (10.42 %) [24] may contribute to a rise in the blood sugar levels and the glycemic index of the concerned. Several low-calorie sugars or artificial sweeteners are used today in zero-sugar soda drinks or snack foods [16]. Despite rising controversies on the use of some of these low-calorie sugars in food, there are more and more such products in the market because of the ´expected health benefits´. In this light, more carefully planned and executed studies on foods with LCS are required to enable decision-makers to make more informed decisions on their future use in different food products.

Calorific values of low-calorie sugars are within the range (0–2.6 kcal/g), compared to sucrose with a calorific value of 4 kcal/g [25, 26]. The glycemic index for sucrose is 65-80.0 compared to 0-1 for most low-calorie sugars) [27]. Because foods with LCS or alternative sweeteners are recommended to people with life-threatening ailments such as diabetics, overweight etc. we hypothesized that it could be used as an osmotic dehydrating agent to give products of low sugar content and consequently low glycemic index.

Studies on the kinetics and mathematical modeling of OD process of plantain using low-calorie sugars (LCS) are scarce [29]. Kinetics and mathematical modeling of mass transfer during OD process give valuable information on the understanding of the mechanisms, composition of dehydrated material and operational design. Empirical models such as Peleg, Azuara and Page models having parameters with physical meaning have been widely used to model the rate of dehydration of different plant-based materials [8, 30, 31]. The aim of this work was to study the osmotic dehydration of unripe plantains using the commercial LCS Sussli as an osmotic agent. We report for the first time the effect of temperature, solution concentration, thickness and sample / solution ratio on mass transfer as well as the predictive capacity of Peleg, Azuara and Page's equations for the OD process.

2. Materials and Methods

2.1. Preparation of Plantain

Fresh fully matured and unripe plantain fruits (*Musa paradisiacal* L.) of the false horn variety were bought from a local farmer in Bamenda, North West region of Cameroon (Latitude 5° 57′ 34.92″ and longitude 10° 08′ 45.49″ and transported to the food technology laboratory at National Polytechnic University Institute (NPUI) Bamenda. The plantain samples were kept under laboratory temperature (25±2 °C) and used within 24 hours for the experiments. The plantain fruits were washed with distilled water, peeled and sliced into 2.5, 5, and 10 mm thickness using a stainless-steel knife. The thicknesses of the slices were measured with vernier calipers. Osmotic solutions of different concentrations of a commercial LCS (12.5, 25 and 50 %) were prepared by dissolving the required quantity in distilled water.

2.2. Osmotic dehydration procedure

To evaluate the effect of process parameters on the mass transfer of the OD process, 3 different concentrations of the solution (12.5, 25 and 50 %) and slices of thickness (2.5, 5, and 10 mm) were used in the study. The plantain slices were immersed in 200 ml beakers containing the respective solutions in the ratio 1:10 (w/v). The beakers were allowed to stand at room temperature (25 ±2 °C) and at varied time intervals (10, 20, 40, 60, 80, 100, 120 and 140 min). The effect of sample solution ratio (1:5, 1:10 and 1:20 w/v) was evaluated at ambient temperature (25±2 °C), with slices of thickness 5 mm in 12.5 % solution concentration. The influence of temperature (30, 40 and 50 °C) on mass transfer was investigated with slices of thickness 5 mm in 12.5 % LCS concentration. and material to solution ratio of 1:10 (w/v). After each experiment, samples were washed with distilled water and gently blotted using a tissue to remove the excess water and the weight taken using an electronic balance (0.01 precision KD-CN 1107260) to evaluate the change in mass.

2.3. Determination of mass transfer parameter

The initial moisture content of raw fresh plantain and OD plantain slices after each contact time was determined by drying in an electro-thermal oven (Model DHG SearchTech Instruments, Germany) at 105 °C until constant weight [32]. The water loss (WL) and solid gain (SG) were determined according to the method described by [33] using equations 1 and 2 respectively.

WL (%=$\frac{WiXi-WfXf}{Wi}$ $x100$ **…………………………….................................. Equation 1**

SG (%) = $\frac{WfXstf - WiXsti}{Wi}$ $x100$ **…………………………................................... Equation 2**

Where WL and SG are moisture loss and solid gain respectively, Wi and W_f are respectively the initial and final weights of samples in grams for a given run; X_i and X_f are the initial and final moisture content for a given run, respectively and X*sti* and X*stf* are the initial and final solid content for each run.

2.4. Mathematical Modeling

The Peleg, Azuara and Page's models were tested using kinetic data from different experiments on temperature effect (Table 1). These models are frequently used in the literature to describe the drying kinetics of some foods and vegetables.

Table 1: List of different drying models used

No	Model	Model equation	Reference
1	Peleg	$X = X_0 \pm \frac{t}{K_1 + K_2\, t}$	[8, 31]
2	Azuara	$XG = \frac{\beta i\ .\ tXG\infty}{1+\beta i.\ t}$	[8, 15]
3	Page	$W_{a\ or\ s} = exp^{(-At^B)}$	[8, 31]

To evaluate the constants K_1, K_2, A, B and βi in the respective models, the equations were expressed in linear forms as follows:

Peleg´s model:

$$\frac{t}{x - x0} = K1 + k2\ (t)$$ Eq.3

X is the amount of water or solids at time t, X_0 is the initial amount of water or solids, t is the time, and k1 and k2 are Peleg constants.

Page's Model was linearized to

$$Ln\ (-\ln W) = Bln\ t + \ln A$$ Eq. 4

where W represents the water lose or solid gain at time t; A and B are Page constants

While the Azura was simplified to

Eq. 5

$$\frac{t}{WLt} = \frac{1}{WL\infty}(t) + \frac{1}{\beta 1 WL\infty}$$

$$\frac{t}{SGt} = \frac{1}{SG\infty}(t) + \frac{1}{\beta 2 SG\infty} \quad \text{Eq. 6}$$

WLt and SGt are the average percentage of water loss and solid gain at any time, WL∞ and SG∞ are the moisture loss and solid gain fraction at equilibrium, β_1 and β_2 are the constants related to the rate of water lose and the rate of solid diffusion into the product respectively. The moisture loss and solid gain fraction at the equilibrium time (β_1 and β_2) were obtained from the slopes and intercepts of plots of equations 5 and 6.

2.5. Statistical analysis

Analysis of variance (ANOVA) on Stagraphics Centerion version XVII.II. was used to test significant differences between means. Duncan multiple range test was used to detect differences between means. The fitting of the mathematical functions (Peleg, Azuara, and page) to the experimental points was done with Sigma plot (Version 14.5 Systat Software Inc.). The determination coefficient (R^2) and the root mean square error (*RMSE*) were used to evaluate the goodness of fit of the model. The best model was that with the highest R^2, and the least RMSE. Graphs were plotted using Microsoft Excel 2007.

3. Results and Discussions

3.1. Effect of concentration on moisture loss and solid gain

Figures 1 and 2 show the moisture loss and solid gain as affected by the concentration of osmotic solution at different slice thicknesses. In general, there was increased moisture loss and solid gain associated with increased concentration of osmotic solution at all slice thicknesses. This observation could be because an increase in solute concentration accentuates the osmotic pressure gradient between the fruit and the solution, hence establishing an enhanced driving force for mass transfer. The time required to observe a pronounced WL was 100, 60 and 20 min for the 50 % solution for the 2.5, 5 and 10 mm slices (Figures 1a, b and c). [34] made a similar observation and explained that the delayed time necessary to observe a pronounced effect on WL was required for a reduction in the viscosity of the solution in order to overcome its resistance to permit loss of water. Meanwhile for SG, there was no significant difference ($P<0.05$) at concentration 25 and 50 % concentrations especially for the 5 and 10 mm slice thickness (Figures 2 a and b).

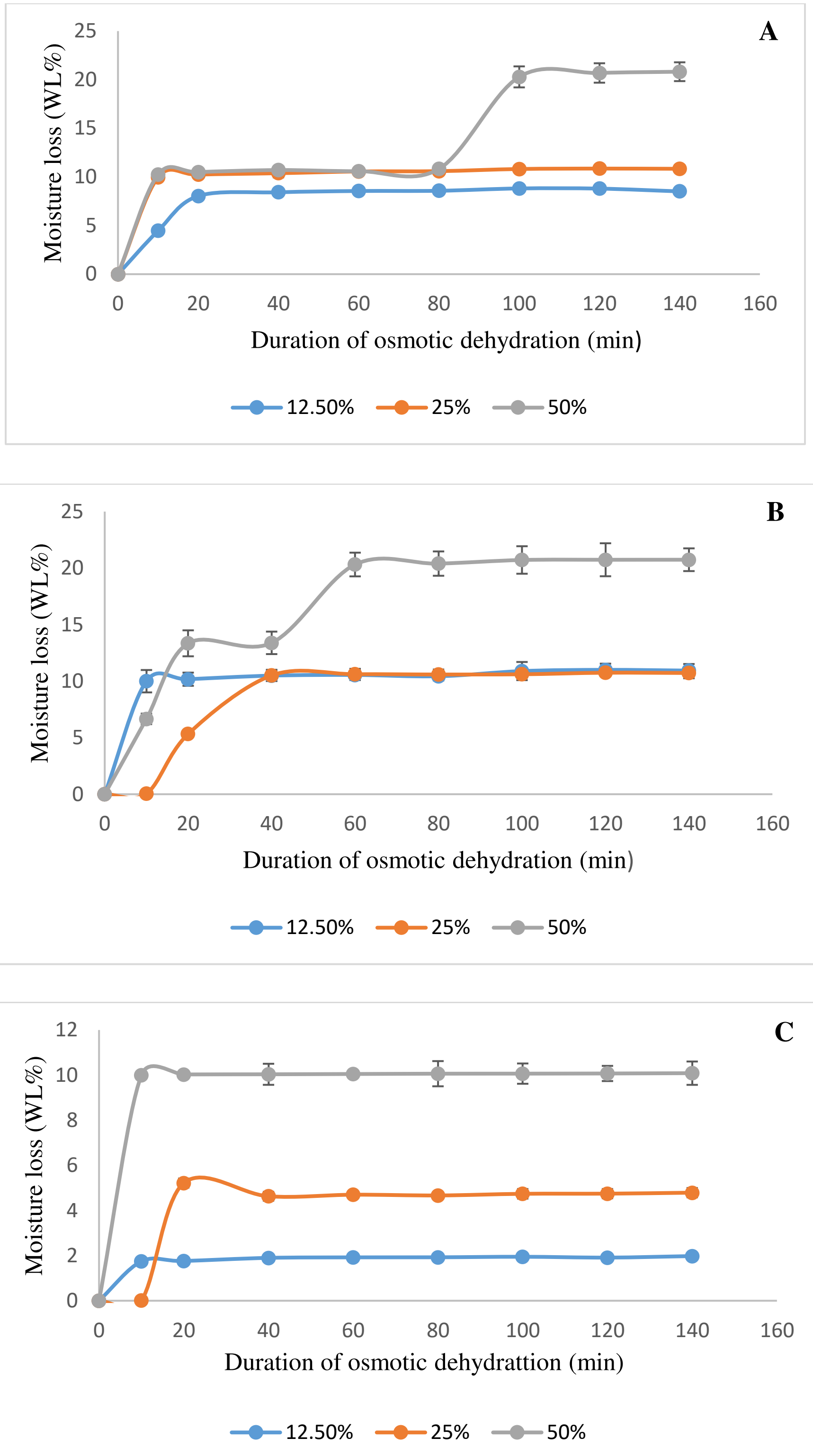
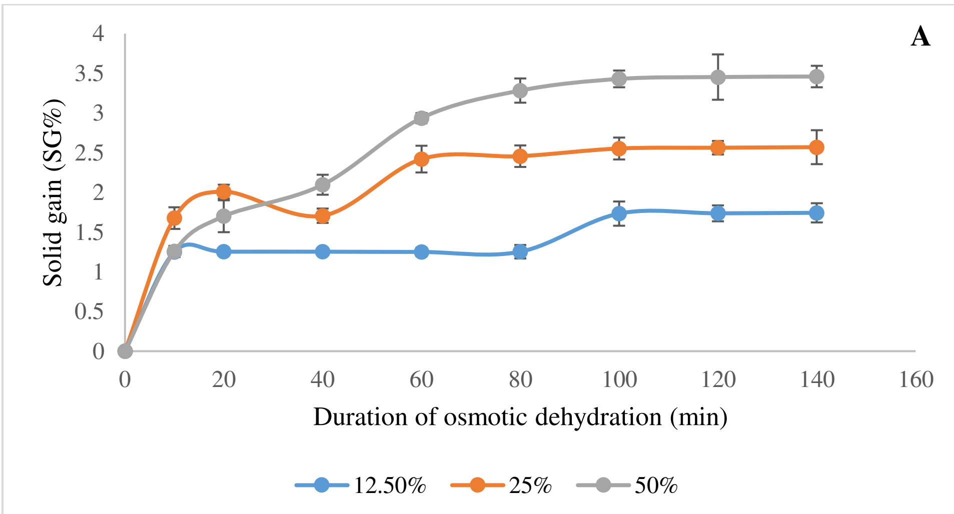
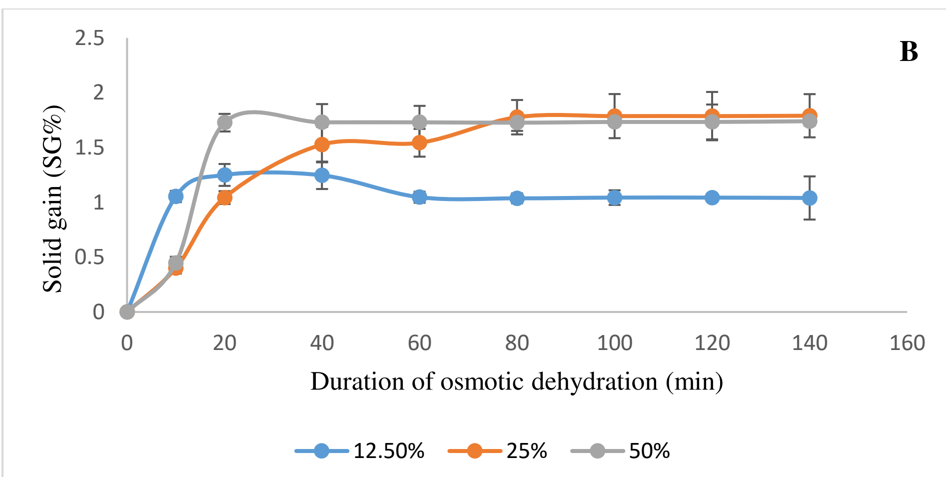


Fig. 1 Effect of solution concentration on moisture loss during osmotic dehydration of plantain

(a) 2.5 mm (b) 5 mm and (c) 10 mm slice thickness

The results also demonstrated that water loss (Figure 1) and solid gain (Figure 2) were higher at initial stages of osmosis and finally slowed down and became stable in later stages. These results corroborate with findings of [35, 36] on osmotic dehydration of banana and broccoli stalk slices respectively. [36] explained that the higher water removal from the sample during the early stage of the process reduces concentration gradient between the solution and the sample and because of possible deposition of the solute in the pores which subsequently decreases the driving force, thus lowering the mass transfer rate.





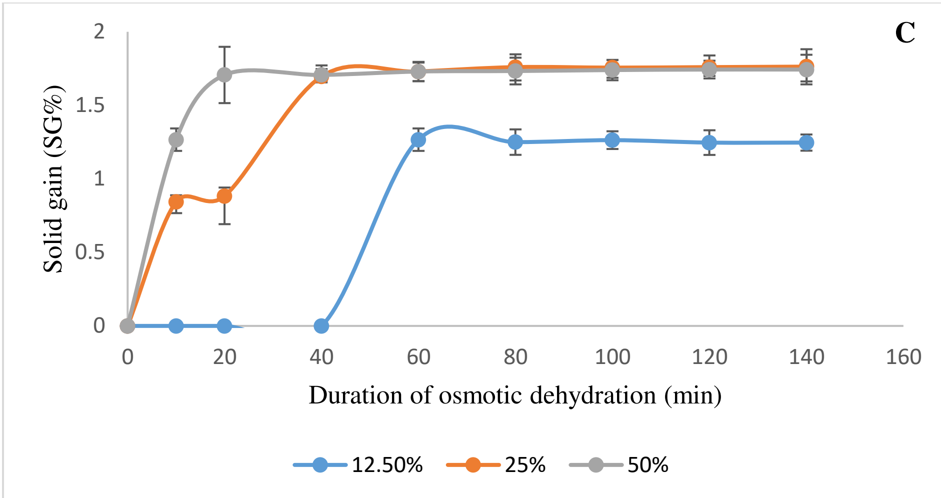
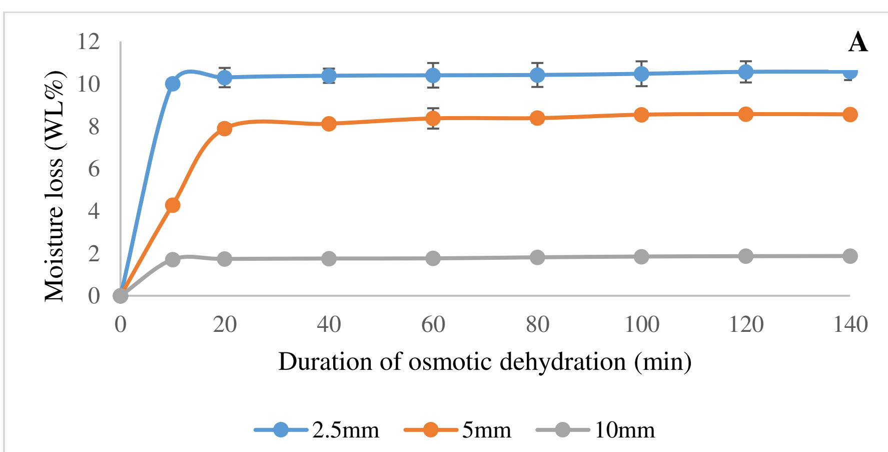
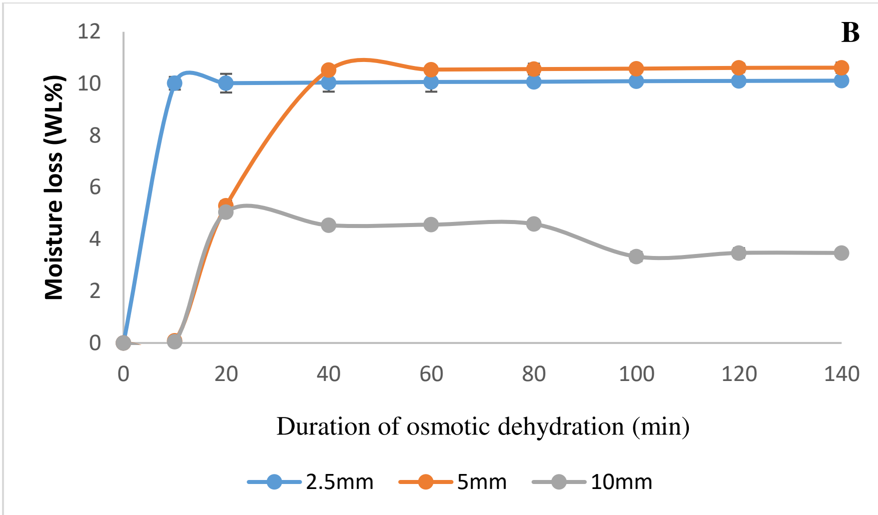


Fig. 2 Effect of solution concentration on solid gain (SG) during osmotic dehydration of plantain (a) 2.5 mm (b) 5 mm and (c) 10 mm slice thickness

3.2. Effect of thickness on moisture loss and solid gain

Figures 3a, b, and c show the effect of plantain slice thickness on moisture lose while figures 4a, b and c depict the effect on solid gain. The percentage moisture loss decreased significantly with increased slice thickness; 10 % in 2.5 mm to 4.5 % in 5 mm and 1.7 % in 10 mm at 12.5 % solution concentration. However, the final moisture lose was not significantly different for 5 and 10 mm at higher concentrations. Solid gain (Figures 4a, b and c) was significantly higher at all concentrations for the 2.5 mm thick slice compared to 5 and 10 mm... The results are similar to those of [11, 23, 37] for osmotic dehydration of plantain slices**.** All authors reported a decrease in the rate of water loss and solids gain with increase in slice thickness. According to [38] this may be due to the width ratio and the increase of surface area in contact with the osmotic solution. [9] explained that the thicker slice, dehydrated more slowly because the length of the diffusion path is greater compared to the smaller pieces.





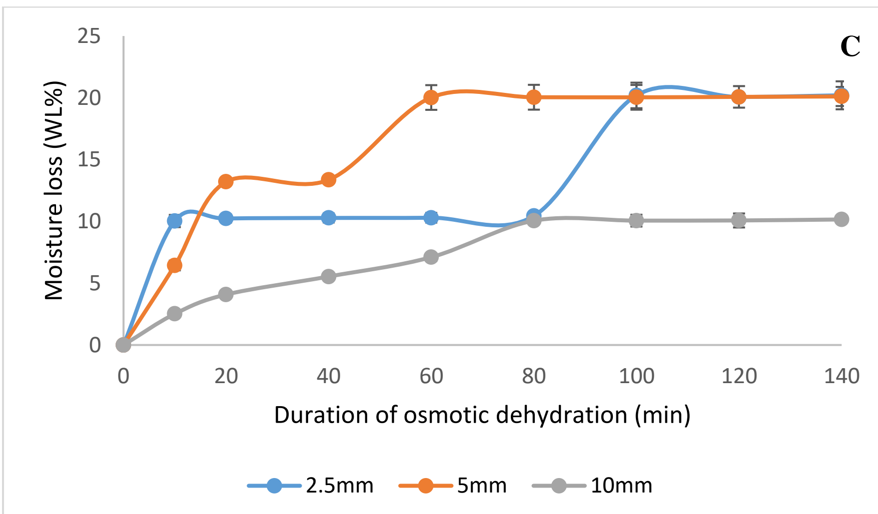
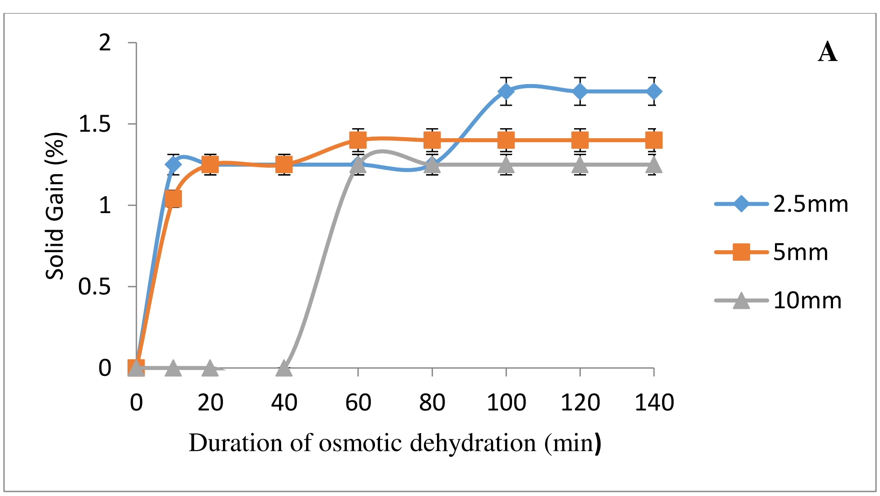


Fig.3 Effect of slice thickness on moisture loss during osmotic dehydration (a) 12.5 % concentration (b) 25 % concentration and (c) 50 % concentration



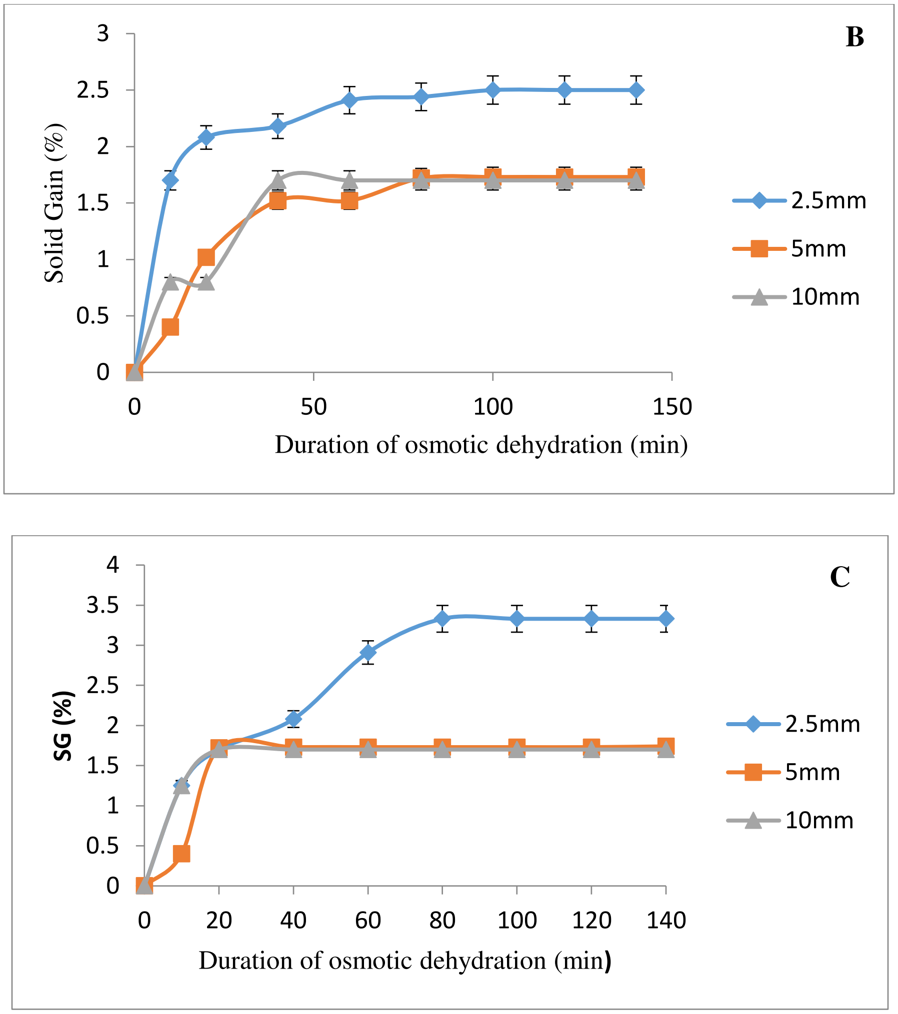


Fig.4 Effect of slice thickness on solid gain during osmotic dehydration(a) 12.5 % concentration (b) 25 % concentration and (c) 50 % concentration

3.3. Effect of sample / sugar solution ratio on moisture loss and solid gain

Figures 5 (a and b) represent the effect of sample /solution ratio (1:5 to 1:20 w/v) on moisture loss and solid gain of plantain slices during osmotic dehydration. Moisture loss from plantain slices increased with increase in sample/ solution ratio with about double the value recorded at 1:20 w/v compared to that at lower ratios. There was no significant difference ($P<0.05$) in moisture loss between sample/solution ratios 1:5 and 1:10. On the other hand, there was a decrease in SG with an increase in sample/solution ratio even though no significant difference was observed between 1:10 and 1:20 ratios. This observed trend in moisture loss corroborate with that reported by [39]**.** The authors reported that an increase in osmotic sample mass/solution ratio resulted in an increase in both the solid gain and moisture loss of the osmotic dehydrated samples**.** As dehydration progresses, the osmotic solution becomes increasingly diluted and the driving force for further release of water drops, thus there is low WL and SG at low solution to sample [40]. Thus, 1:20 ratio represents the suitable sample /solution ratio for OD of plantain in the low-calorie sugar solution.

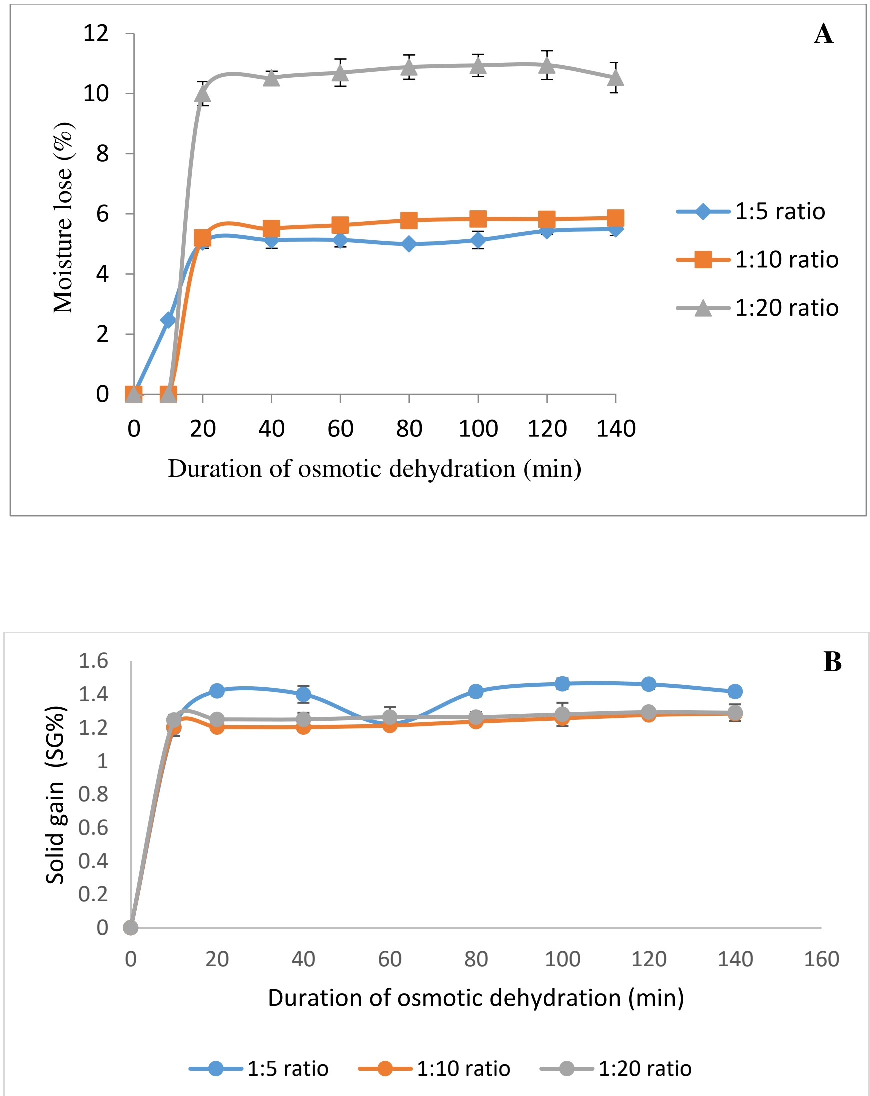


Fig.5 Effect of sample /solution ratio on (a) moisture loss (b) Solid gain during osmotic dehydration of plantain slices at concentration 12.5 % and slice thickness 5 mm

3.4. Effect of temperature on moisture loss and solid gain

Figures 6 (a and b) illustrates the effect of temperature on moisture loss and solid gain during osmotic dehydration of plantain. It was observed that the moisture loss (WL) increased with increased temperature. However, above 1h, moisture loss at 40 °C was significantly higher compared to loss at 50 and 30 °C. On the contrary, solid gain (SG) increased significantly with increase in temperature all through the experimental period.

This corroborates with findings by [35, 41] who reported increased moisture loss and SG with increased temperatures during osmotic dehydration of papaya and banana slices respectively. The researchers indicated that, higher temperatures decrease the viscosity of the osmotic solution and external resistance to mass transfer rate at the sample surface thus, facilitating the outflow of water. On their part,) [42] working on osmotic dehydration of carrot slices associated increase moisture loss at higher temperatures to rise in fruit membrane permeability which promotes swelling and plasticization of cell membrane, and better water transfer characteristics on the product surface due to lower viscosity of the osmotic medium. Regarding the decreased moisture loss observed at 50 °C, [20] made similar observation on the influence of OD on the structural properties of plantain. The authors attributed this decrease in WL at higher temperature (above 40°C) to increased density (reduced porosity) of samples, due to rapid solute impregnation and starch gelatinization. They explained that starch swelling in amorphous areas due to water absorption, reduces water outlet, in addition to the solute barrier which prevented the flow of water and consequently reduced WL at higher temperature. Osmotic solution temperature of 40°C could be retained as the best temperature.

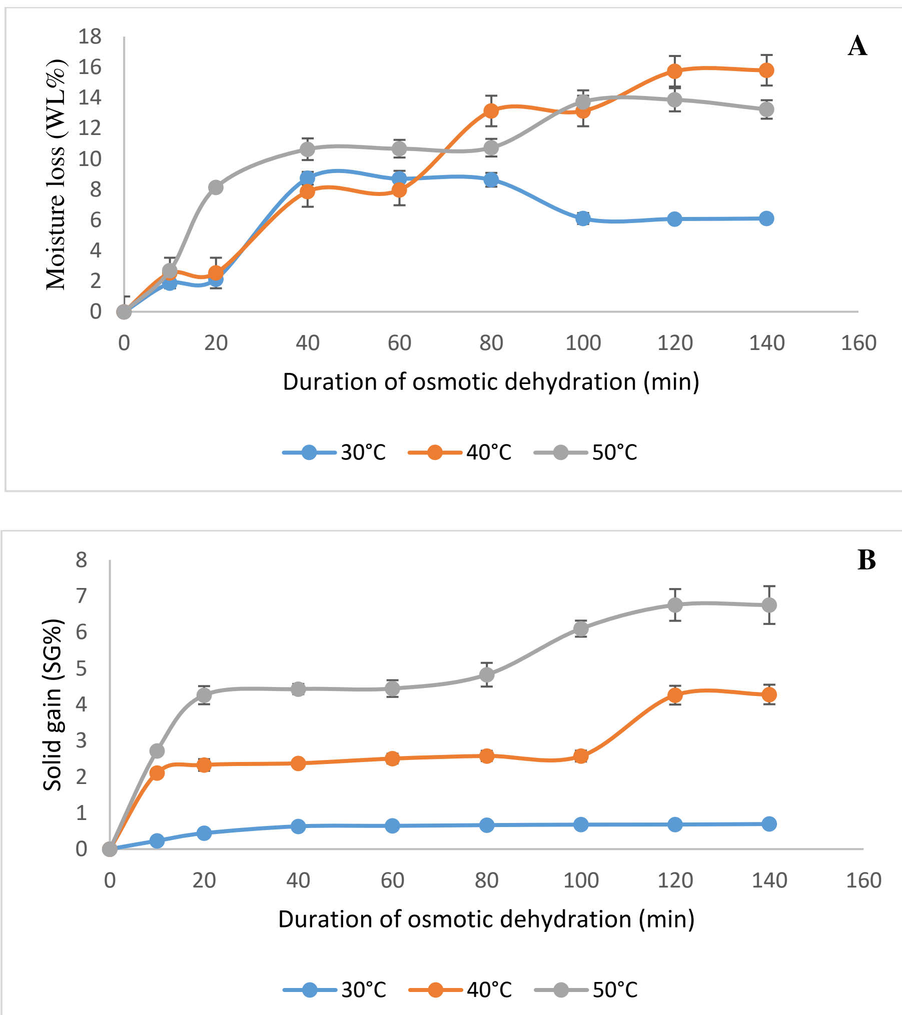


Fig. 6 Effect of temperature on (a) moisture loss and (b) Solid gain during osmotic dehydration of plantain at concentration 12.5% and slice thickness 5mm

3.5. Mathematical modeling of water loss and solid gain during OD process

In this study, the Peleg, Azuara and Page equations were used to evaluate the osmotic dehydration kinetics of plantain slices using LCS. Parameters of the three equations calculated from the plots of data obtained at 30, 40 and 50 °C, plantain slices/osmotic solution ratio 1:20, slice thickness of 5mm, and 12.5 % solution concentration are shown in table 1. Regression coefficients (R^2) and Root Mean Square Errors (RMSE) values were used to check the validity of the models. R^2 values from the PELEG model were very close to unity while the corresponding RMSE values were all less than 0.065 which was an indication of the model ability to adequately describe the osmotic dehydration process of plantains with the low-calorie sugar.

Table 2: Parameters for the equations used to model the kinetic data for the osmotic dehydration of plantain

AZURA Model								
	Weight Loss				Solid Gain			
Temp (°C)	β_1	WL∞	R^2	RMSE	β_2	SG∞	R^2	RMSE
30	0.013	14.08	0.841	1.042	0.052	0.812	0.988	5.979
40	0.005	41.67	0.511	1.073	0.031	4.42	0.764	5.537
50	0.026	18.18	0.942	0.601	0.029	9.708	0.935	1.689
PELEG Model								
	K_1	K_2	R^2	RMSE	K_1	K_2	R^2	RMSE
30	0.040	-0.017	0.999	0.017	0.005	-0.030	1	0.0009
40	0.110	-0.020	0.997	0.046	0.077	-0.033	0.998	0.065
50	0.056	-0.019	0.999	0.019	0.120	-0.037	0.998	0.065
PAGE Model								
	A	*B*	R^2	RMSE	*A*	*B*	R^2	RMSE
30	-0.206	0.503	0.890	0.153	4.468	-0.539	0.9100	0.147
40	-0.316	0.457	0.915	0.121	-0.384	0.234	0.691	0.136
50	-0.652	0.302	0.743	0.154	-1.520	0.124	0.882	0.068

The Peleg constant K_1 relates to the initial mass transfer coefficients for SG and WL. The parameter K_2 describes the rate of SG and WL at the equilibrium stage of osmotic dehydration process. The K_1 parameter for WL of the Peleg's model increased with solution temperature from 30 to 40°C and then decreased at 50°C. [18] reported that the $1/K_1$ of the Peleg's model describes the initial dehydration rate and in this study it was highest at 30 °C followed by dehydration rate at 50 °C and then decreased at 40 °C, as reflected in the values of K_1 (Table 2). This suggests that initial rate of mass transfer (WL) decreased up to 40 °C and then increased thereafter. [28] also indicated that the lower the K_2 parameter, the higher the water removal at equilibrium. The trend for K_1 parameter for SG increased steadily with elevation in temperatures meanwhile there was an observed decreased in K_2 values with temperature. [8] reported decreased K_1 values for WL and SG with increased temperature for Peleg model in seedless guava (*Pisidium guajava* L.). This implies initial rate of SG decreased with increased temperature while the equilibrium SG increased with increasing temperature. The main objective of this section was to predict the quantity of water loss and solid gain using different models and determine the most suitable for model osmotic dehydration process of unripe plantain using low calorie sugar. However, single factor evaluation of osmotic dehydration as presented here may not show clearly the correlation between responses and various factors as well as the interaction between the different factors.

4. Conclusion

Low calorie sugar was successfully used to carry out the osmotic dehydration of raw plantain slices with results comparable to those obtained with salt and sucrose solutions. All parameters tested slice thickness, solution concentration, sample /solution ratio, and temperature had significant effects on Water loss and Solid gain. Peleg's model fits best the experimental data due to high R^2 values (>0.999) and low RMSE values. Plantain slice of thickness 5mm, low-calorie sugar solution concentration of 50% at temperature 40°C, and a sample/solution ratio of 1:20 was judged best for osmotic treatment of plantains in low-calorie sugar solution. In the future we will report the optimization of osmotic dehydration of unripe plantain using LCS and the effect on the nutritional, functional and the glycemic properties of its flour in comparison to wheat flour.

List of abbreviations

OD: osmotic dehydration

WL: Moisture loss

SG: Solid gain

RMSE: Root Mean Square Errors

Declarations

Ethics approval and consent to participate: Not applicable

Consent for publication: Not applicable

Data availability statement All the data that support the findings of this study are available with the authors and can be made available upon reasonable request.

Competing: Interests The authors declare no competing interests.

Funding: No funding was received for this study**.** The authors have no relevant financial or non-financial interest to disclose

Author Contribution L.E: Conceptualization, methodology, investigation, writing of original draft. D.B: Conceptualization, methodology, investigation, supervision, writing of original draft. S.J: Conceptualization, methodology, investigation, supervision, writing of original draft.

Acknowledgement: Not applicable

References

[1] Ogidi I.A, Wariboko C. and Alamene A. (2017). Investigation of Some Nutritional Properties of Plantain (*Musa Paradisiaca*) Cultivars in Bayelsa State. *European Journal of Food Science and Technology* Vol.5, No.3, pp.15-35

[2] Folefack, D.P., Fongang Fouepe, G.H., Adamou, K.M., Ebongue, J.-P., Bikoi, A., Noupadja, P., (2017): Analysis of the plantain supply system of markets in the city of Douala. *J. Econ. Sustain. Dev. 8 (6) http://www.iiste.org (ISSN 2222-1700 (Paper) ISSN 2222- 2855 (Online)*

[3] Nafack Tsazeu Judicaël Boris1, Ngo Nkot Laurette1, Kana Sop Marie Modestine (2023): Plantain (*Musa paradisiaca* L.): Production, Consumption and Processing in Cameroon. *American Journal of Food Science and Technology, 2023, Vol. 11, No. 1, 8-14* DOI:10.12691/ajfst-11 -1 -2

[4] Adenekan M.K, Odunmbaku L.A, Lawal O.A (2021): Effect of Pre-Treatment Conditions on the Anti- Nutrients of Dried Unripe Plantain (*Musa Parasidiaca*) and the Application in Dough Making. *International Journal of Advances in Engineering and Management (IJAEM)Volume 3, Issue 8, pp: 1268-1274.* https://doi.org/10.35629/5252-030812681274

[5] Olumba C.C and C.N Onunka (2020). Banana and Plantain in West Africa: Production and Marketing. *Afr. J. Food Agric. Nutr. Dev*. 20(2): 15474-15489. DOI: 10.18697/ajfand.90.18365

[6] Lescot, (2017): La diversite genetique des bananiers. Frui trop focus bananes 208-212

[7] Ngoh Newilah Gérard Bertin, Takam Ngouno Annie, Kendine Vepowo Cédric, Manjia Ngoungoure Solange Ulrich, Njapndounke Bilkissou, Wambo Pascal, Fokou Elie And Etoa François-Xavier (2020). Formulation of Plantain Flour-Based Pasta: Process Optimization and Sensory Evaluation. *Food Sci Nutr Res*. 3(2): 1-11.

[8] Ganjloo, A., Rahman, R.A., Bakar, J., Osman, A. and Bimakr, M. (2011). Mathematical modelling of mass transfer during osmotic dehydration of seedless guava (*Pisidium guajava* L.) cubes. *International Food Research Journal* 18(3): 1105-1110

[9] Rastogi, N. K., Raghavarao, K. S. M. S., Niranjan, K. and Knorr, D. (2002). Recent developments in osmotic dehydration: methods to enhance mass transfer. *Trends in Food Science and Technology* 13(2): 58–69.

[10] Rastogi, N. K. and Raghavarao, K. S. M. S. (2004). Mass transfer during osmotic dehydration of pineapple: Considering Fickian diffusion in cubical configuration. *Lebensmittel-Wissenschaft und-Technologie* 37: 43–47.

[11] More PG and Khodke SU (2019). Effect of slice thickness on overall acceptability of Osmo-convectively dried carrot slices. *International Journal of Chemical Studies;* 7(6): 1 357-1360

[12] Panades, G., Castro, D., Chiralt, A., Fito, P., Nuñez, M. and Jimenez, R. (2008). Mass transfer mechanisms occurring in osmotic dehydration of guava. *Journal of Food Engineering* 87(3): 386-390.

[13] Junqueira J. R de J., Corrêa J. L. G., de Mendonça K. S., de Mello Junior R. E, Souza A. U. (2021). Modeling mass transfer during osmotic dehydration of different vegetablestructures under vacuum conditions. *Food Sci. Technol, Campinas*, 41(2): 439-448.

[14] Bera D. and Roy L**.** (2015). Osmotic Dehydration of Litchi Using Sucrose Solution: Effect of Mass Transfer. *J Food Process Technol,* 6:7. https://doi.org/10.4172/2157-7110.1000462

[15] Jabrayili S., Farzane V., Zare Z., Bakhshabadi H., Babazadeh Z., Mokhtarian M., and CarvalhoI. S. (2016). Modelling of mass transfer kinetic in osmotic dehydration of kiwifruit. *Int. Agrophys.* 30, 185-191 doi: 10.1515/intag-2015-0091

[16] Kapadiya Dhartiben, B. and K.D. Aparnathi (2017). Chemistry and Use of Artificial Intense Sweeteners. *International Journal of Current Microbiology and Applied Sciences*, Volume 6 Number 6 pp. 1283-1296.https://doi.org/10.20546/ijcmas.2017.606.151

[17] Mendonça K. S., de Jesus J. R., Pereira M. C. A. and Corrêa J. L. G. (2014). Osmotic Dehydration of Yacon Slices: Effect of Different Polyols on Mass Transfer Parameters. *Congreso Bresileiro de Engenharia Quimica,* 19 a 22 de outubro.

[18] Cichowska, J., Woźniak, Ł., Figiel, A., Witrowa-Rajchert, D. (2020). "The Influence of Osmotic Dehydration in Polyols Solutions on Sugar Profiles and Color Changes of Apple Tissue". *Periodica Polytechnica Chemical Engineering,* 64(4), pp. 530–538. https://doi.org/10.3311/PPch.14096

[19] Sethi K and Kaur M. (2019). Effect of Osmotic Dehydration on Physicochemical Properties of Pineapple using Honey, Sucrose and Honey-Sucrose Solutions. *International Journal of Engineering and Advanced Technology (IJEAT)* ISSN: 2249-8958 (Online), Volume-9 Issue-1

[20] Gallegos-Marin et al., (2016). Structural properties change during osmotic drying of plantain (*Musa paradisiaca* AAB) and its role on mass transfer. *Revista Mexicana de Ingenierıa Quımica* Vol. 15, No. 2, 441-456.

[21] Loa J. F. R. B., Kouamé A. F. and Yao N. B. (2017). Osmotic Dehydration of Plantain Cultivar French (Agnrin) in Binary Solution (Sucrose or Glucose). *International Journal of Current Microbiology and Applied*

Sciences ISSN: 2319-7706 Volume 6 Number 10 pp. 4816-4824 .https://doi.org/10.20546/ijcmas.2017.610.449

[22] Chavan U. D. Prabhukhanolkar A. E., Pawar V. D. (2010). Preparation of osmotic dehydrated ripe banana slices. *J Food Sci Technol* 47(4):380–386.https://doi.org/10.1007/s13197-010-0063-8

[23] Haque Md. R., Hosain Md. M., Kamal Md. M., Islam Md. R., MondalS. C. (2020). Optimization of osmotic dehydration parameters of banana under pulsed microwaveconditions by response surface methodology. *J Microbiol Biotech Food Sci:* 9 (6) 1053-1059. https://doi.org/10.15414/jmbfs.2020.9.6.1053-1059

[24] Adewole M. B. and Duruji R. W. (2010). Quality assessment of plantain (*Musa paradisiaca* L.) as affected by different ripening methods. *African Journal of Biotechnology* Vol. 9(38), pp. 6290-6293.

[25] Washburn Carolyn and Nedra Christensen, (2017). Sugar Substitutes: Artificial Sweeteners and Sugar Alcohols. Food Nutrition, Utah State University Corporative Extension.

[26] Helen Turner (2017). Artificial Sweeteners. Health Equalities Group, 151 Dale Street, Liverpool, L2 2JH United Kingdom.

[27] Redmer Jacqueline (2014). Understanding sweeteners. VA office of Patent Centered Care and Cultural Transformation

[28] Cichowska J., Figiel A., Stasiak-Rózanska L. and Witrowa- Rajchert D. (2019). Modeling of Osmotic Dehydration of Apples in Sugar Alcohols and Dihydroxyacetone (DHA) Solutions. *Foods,* 8, 20. https://doi.org/10.3390/foods8010020

[29] Alakali J. S., S. V. Irtwange and P. A. Yusuf. (2008). "Mass Transfer Considerations in Osmotic Dehydration of Plantain (*Musa Paradisiaca*) Chips". *Agricultural Engineering International: the* CIGR E-journal. Manuscript FP 07 026. Vol. X.

[30] Langari F. S. and Movagharnejad K. (2015). Experimental Study and Mathematical Modeling of the Osmotic Drying Process. *Iranian Journal of Chemical Engineering* Vol. 12, No. 3, IAChE.

[31] Azoubel P. M. and Murr F. E. X. (2004). Mass transfer kinetics of osmotic dehydration of cherry tomato. *Journal of Food Engineering* 61, 291–295.

[32] AOAC (2000): Association of Offical Analytical Chemists. Offical Methods of Analysis. 17th ed.

[33] Zhelyazkov S. et al., (2020). Optimization of osmotic dehydration parameters for sweet cherries (*Prunus avium*) using response surface methodology. *Bulgarian Chemical Communications,* Volume 52, Issue 4 (pp. 500-505).https://doi.org/10.34049/bcc.52.4.5304

[34] Yadav B. S, Yadav R. B. and Jatain M. (2012). Optimization of osmotic dehydration conditions of Peach slices in sucrose solution using respond surface methodology. *Journal of Food Science* 49(5):547-555. https://doi.org/10.1007/s13197-011-0298-z.

[35] Jalali V. R. R., NarainN., da SilvaG. F. (2008). Effect of osmotic pre-dehydration on drying characteristics of banana fruits. *Ciênc. Tecnol. Aliment. Campinas,* 28(2): 269-273, ISSN 0101-2061.

[36] Md Salim N. S., Y. Garièpy and V. Raghavan (2016). Effects of operating factors on osmotic dehydration of broccoli stalk slices. *Cogent Food & Agriculture*, 2: 1134025. http://dx.doi.org/10.1080/23311932.2015.1134025

[37] Paradkar V. and Sahu G. (2018). Studies on Drying of Osmotically Dehydrated Apple Slices. *International Journal of Current Microbiology and Applied Sciences*7(11): 633-642

[38] Kolawole O. Falade A, Joseph C, Igbeka B, Funke AA. (2007). Kinetics of mass transfer, and colour changes during osmotic dehydration of watermelon. *Journal of Food Engineering,*80:979-985.

[39] Akbarian M., Ghasemkhani N., and Moayedi F. (2013). Osmotic dehydration of fruits in food industries: A review. *International Journal of Bioscience.* Vol. 3 No. 12, p. 1-16.

[40] Ramya, V. and Jain N.K. (2016). A Review on Osmotic Dehydration of Fruits and Vegetables: An Integrated Approach. *J. Food Process Eng.*, 40, e12440

[41] Islam Md Z., Shuvo Das, Monalisa K. and Sayem A.S.M. (2019). Influence of Osmotic Dehydration on Mass TransferKinetics and Quality Retention of Ripe Papaya(*Carica papaya L*) during Drying. *AgriEngineering,* 1, 0–14.https://doi.org/10.3390/agriengineering1020016

[42] Singh S. K. and Gangwar Varshika (2020). Effect of temperature and concentration of osmotic solution on moisture loss and solid gain during osmotic dehydration of carrot. *International Journal of Chemical Studies.* 8(5): 2017-2022. DOI: https://doi.org/10.22271/chemi.2020.v8.i5ab.10598

How to cite this article:

Lobe Elias Eyembe[12], Divine Bup Nde[1]*, Sonchieu Jean[3]

Osmotic Dehydration Kinetics of Plantain (*Musa paradisiaca*) using a Low-calorie Sugar

Discover foods