The Open Chemical Engineering Journal

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RESEARCH ARTICLE

Drying of Banana-Stepwise Effect in Drying Air Temperature on Drying Kinetics

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Abstract:

Objective:

Three different varieties of banana namely Dwarf Cavendish (Ankleshwar region), Lacatan (Valia region) and Harichal (Bharuch region) were collected from the south Gujarat region, India to check the drying parameters. A pilot scale natural draft tray dryer was used for the drying experimental work.

Methods:

The performance of all the varieties of banana were verified with and without blanching operation. Change in colour, texture, shrinkage and appearance were studied. Blanching has a remarkable effect on the appearance and shrinkage of the banana samples.

Results:

On the other side, temperature does not show any significant effect on the shrinkage. For the Lacatan and Harichal banana samples, shrinkage was found to be very less at 60 ° C and 70 ° C, while for Dwarf Cavendish sample, shrinkage was found more effective at all varying temperature ranges.

Conclusion:

Appearance, colour and texture of Dwarf Cavendish and Harichal were found to be significant at 70 ° C and 80 ° C, while for Lacatan, no such acceptable changes were observed. Overall, blanching was found to be effective in improving the appearance and colour of all varieties of banana.

Keywords: Natural draft drying, Banana, Shrinkage, Blanching, Lacatan, Dwarf cavendish.

Article History	Received: April 19, 2020	Revised: June 18, 2020	Accepted: June 19, 2020

1. INTRODUCTION

Agricultural products like vegetables and fruits play a vital role in nutrition supply and as human diet. Approximate loss of agricultural products in the developing country, like India after cultivation (Post- growing) is about 20-50%, which is actually the highest number counted as far as the economy is concerned. Banana is a highly popular fruit, which provides carbohydrates and other minerals in good quantity and is considered a prime fruit in India [1 - 3]. Due to limited shelf life of the banana, different methods of maintaining the quality like cooling methods [4 - 11] and freezing technology [12 - 19] were implemented. Being very sensitive to temperature, banana was exposed to drying processes to increase the life span [20 - 28]. Banana can also be dried by simply air drying and dehydration or freezing [29 - 31]. These methods of banana processing are found to have degrading effects like decolourization, unbalanced sugar content, texture difference, etc. Better quality banana products can only be produced with natural mild drying [32,33]. Drying mechanism was applied in different modes to achieve better and good quality of banana product. Drying mechanism is better applied with banana slices kept in the heat pump drying loop. Effect of temperature and thickness of banana slices are the predominant characteristics that play a role in the drying operation. Moisture diffusivity

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increases with a gradual increase in temperature, which is expected [33,34]. Energy and exergy analysis using first and second law of thermodynamics plays a vital role in determining the drying characteristic of banana under solar drying techniques [35]. Drying of banana not only includes the simple removal of moisture but also includes various other factors like shrinkage, texture, appearance and so on. Different parameters like pH, bulk density, yield, water holding capacity and oil holding capacity are specific in value to identify the optimum bananas crop. While observing the nutritional effect, it was found that moisture and other carbohydrates were reduced while drying and other ash moisture and protein-fats were increased. A significant effect in terms of reduction was also reported on specific anti-nutritional compositions, which is a breakthrough for the long usage of banana [36]. Application based study was also carried out on preparation of smoothies using dehydrated banana. Different compositions of dehydrated banana were taken into consideration for the preparation of smoothies focusing on parameters like color, texture, appearance, density, viscosity, flavor, sweetness determined experimentally or analytically [37]. A study on drying kinetics of two varieties of banana of Bangladesh was also compared at three different temperatures of 45 º C, 55 º C and 65 º C with different slices thickness. In the present work, experiment was done on three different varieties of banana (Dwarf Cavendish, Lacatan and Harichal) collected from three different locations of south Gujarat region namely Ankleshwar, Valia and Bahruch. Effect of drying phenomena on colour, appearance and texture was the motive of the work for the commercialization of banana chips with better quality. Better performance in terms of colour, shrinkage, texture, appearance was selected for the banana chips production commercially.

2. MATERIALS AND METHODS

Three different varieties of banana (Dwarf Cavendish, Lacatan and Harichal) were collected from different locations like Ankleshwar, Valia and Bharuch, Near South Gujarat region, India respectively. All these varieties were selected based on their source of growth. These three varieties had a moisture content of nearly 75-78% on wet basis. The initial moisture content was calculated by removing the moisture by drying in a heating oven for 24 hours at nearly 110 º C. To keep the result very accurate and precise, all the varieties of banana were taken from the same source and kept in the refrigerator under 5-7 º C till it is used. Diameter and Length measurements were performed using calipers and other measurement instruments considering 4-5% tolerance in each sample. With a margin of $22 \leq D \leq 26$ mm and $130 \leq L \leq 150$ mm, samples were given the shape of a cylinder. Some of the samples were soaked into the boiling water for 0.5-3 min to check the blanching effect. The soaked samples were also cleaned by an ashless paper to remove surface moisture. Continuous weight loss with respect to time and temperature and sample dimension change (Diameter, Length and Volume) were recorded simultaneously after each sample of banana with and without blanching operations, using natural draft tray dryer. The moisture loss was calculated on the weighting balance attached to the top of the dryer. The accuracy of the balance was kept ± 0.001 g. The experiments were performed at 60, 70 and 80 º C with time difference of 60, 120 and 180 min with and without blanching operations. Drying is conducted with moisture loss up to 15% (wet basis).

3. RESULT AND DISCUSSION

3.1. Appearance and Nature of Colour

In order to show comparison of the colour, quality and appearance of the dried banana, various digital images have been taken at different temperature and time with and without blanching method. It was investigated through observation of each sample of banana images that Dwarf Cavendish and Harichal were found to be effective in colour and appearance as required by the market demand and thus, it was considered to be authentic results on better selection of the banana variety at specific temperature and time without any use of sophisticated analytical method or techniques for the confirmation.

3.2. Blanching Effect

Blanching is a dehydrating process where the material is heated up for some specific high temperature for a few seconds or minutes to reduce the moisture content of material for further drying operation. Similar procedure was followed in the experimental work where banana samples were blanched in hot water for 0.5 to 3 minutes before performing the drying operation in natural draft try dryer. Experiments were performed on different varieties of banana at different time and temperature with and without blanching operation. It was observed that the drying time of the banana is reduced sequentially with an increase in the blanching time. This is due to the convective heat transfer that takes place, where normally drying time is less and resistance film is not at all formed on the material containing starch. Unblanched banana does not show any significant effect in terms of colour, appearance and drying time. Figs. (**1** and **2**) show the above discussed phenomena in a graphical form. (Refer supplementary data file).

3.3. Shrinkage

While selecting the banana for the chips preparation in the market, shrinkage of banana is the key factor for consideration. In order to justify the shrinkage results physically, it is quite difficult to connect the relation of shrinkage. Experimentally, varieties of banana were observed after each run of drying and specifically, changes in volume, diameter and length were calculated on different basis. These dimensional parameters were related to moisture content of banana after the drying phenomenon. The proposed equations [37] were considered for further finding of every variety of samples of banana.

$$(V|V_0) = AX + B \quad \textbf{(1)}$$

$$(D|D_0)^2 = A'X + B' \quad \textbf{(2)}$$

$$(L|L_o) = A"X + B" \quad \textbf{(3)}$$

A, B, A', B' A'', B'' are the parameters calculated based on a slow and continuous regression method leading to R^2 values at

different temperature, time and varieties as shown in Table **1**. It was investigated through the data obtained by considering the calculation of all parameters and number of equations obtained, which then plotted leads to rigorous results. There is a slight difference in data observed for different temperature range for all three varieties of banana.

(V/Vo), $(D/Do)^2$ and (L/Lo) calculated values were obtained using a set of equations (1) to (3), while parameters were connected using a set of equation parameters (4) to (9) given below.

$$A = 0.521234\, X_o^{0.874126} \quad \textbf{(4)}$$

$$A' = 0.781259\, X_o^{-0.258369} \quad \textbf{(5)}$$

$$A'' = 0.897456\, X_0^{0.874965} \quad \textbf{(6)}$$

$$B = \frac{0.52413 - 0.85497\, X_0}{8.74125 - 2.587432\, X_o} \quad \textbf{(7)}$$

$$B' = \frac{0.12036 - 0.02589\, X_0}{-4.74125 + 6.25178\, X_o} \quad \textbf{(8)}$$

$$B'' = \frac{0.78942 - 0.48521\, X_0}{5.25879 + 0.25137\, X_o} \quad \textbf{(9)}$$

The average % AE for the (V/Vo), $(D/Do)^2$ and (L/Lo) for Dwarf Cavendish banana variety is 4.35, 4.78 and 1.65%, respectively, while maximum error observed is 8.40, 8.77 and 2.81%, respectively as shown in Table **2**. There is not much difference in the % error of the variables calculated.

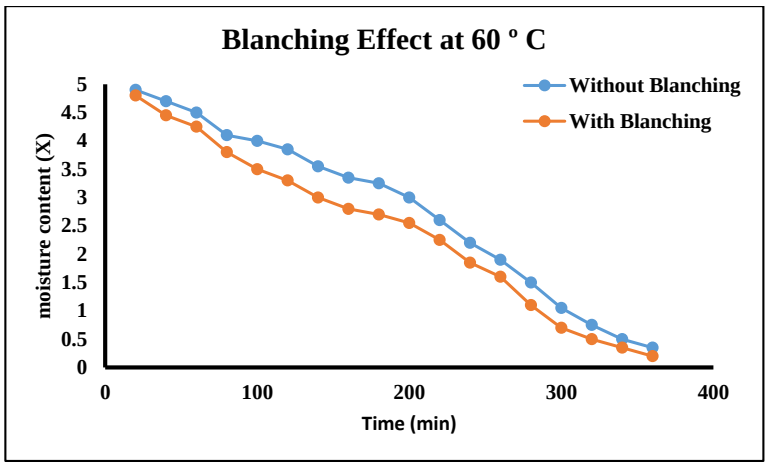

Fig. (1). Effect Of Blanching On Dwarf Cavendish Banana At 60 ° C Temperature

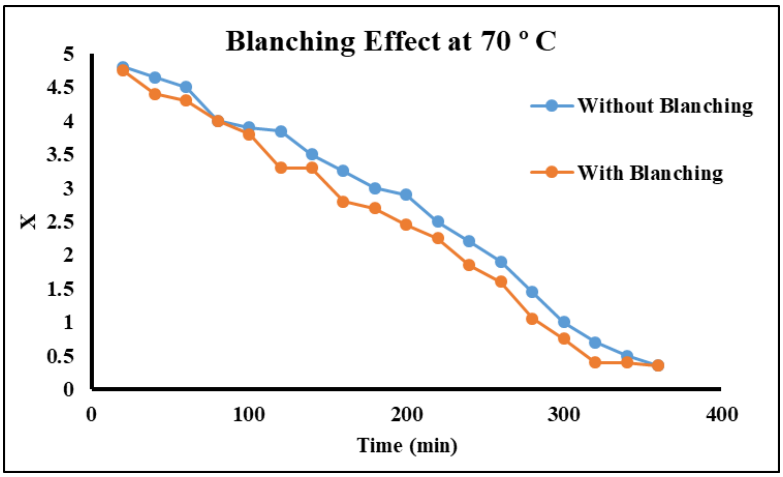

Fig. (2). Effect Of Blanching On Dwarf Cavendish Banana At 70 ° C Temperature

Table 1. Parameters (A, B, A', B', A", B") calculated using set of equations (1 – 3)

Variety of Banana	Temperature (° C)	Equation -1			Equation - 2			Equation-3		
		A	B	R^2	A'	B'	R^2	A"	B"	R^2
Dwarf Cavendish,	60	0.2526	0.0471	0.8982	0.1888	0.1147	0.9587	0.2521	0.0254	0.9152
	70	0.1856	0.2541	0.9256	0.2425	0.0147	0.9682	0.1778	0.0925	0.9567
	80	0.2253	0.0781	0.9587	0.1564	0.1123	0.9164	0.2522	0.1110	0.9647
Lacatan,	60	0.2089	0.1478	0.9136	0.2131	-0.0678	0.9251	0.0789	0.1865	0.9514
	70	0.1132	0.2157	0.9401	0.1478	0.1234	0.9165	0.2897	0.0014	0.9612
	80	0.2287	-0.0524	0.9187	0.1987	0.0784	0.9365	0.1879	0.1474	0.9546
Harichal,	60	0.0925	0.1125	0.9425	0.1478	0.1978	0.9506	0.2514	0.0478	0.9287
	70	0.1287	0.0254	0.9278	0.2029	-0.0741	0.9201	0.1180	0.1245	0.9478
	80	0.1254	0.0365	0.9220	0.1425	0.1178	0.9324	0.2054	0.0789	0.9610

Table 2. Absolute % error calculation for dwarf cavendish banana variety at three different temperature

Drying Temp. (° C)	X	V/V_o Exp.	V/V_o Calc.	% AE for V/V_o	$(D/D_o)^2$ Exp.	$(D/D_o)^2$ Calc.	% AE for $(D/D_o)^2$	L/L_o Exp.	L/L_o Calc.	% AE for L/L_o
60	5.245612	0.591245	0.610235	3.211866	0.682525	0.734561	7.624043	0.887802	0.898795	1.238226
	4.854678	0.652514	0.692512	6.129705	0.724512	0.751425	2.334398	0.854565	0.864578	1.171707
	4.982501	0.814729	0.854212	4.846151	0.782546	0.828245	5.839784	0.798452	0.801102	0.331892
70	4.250198	0.921245	0.947836	2.886420	0.721245	0.784512	8.771915	0.741278	0.758965	2.386149
	4.147895	0.846585	0.885254	4.567645	0.761245	0.808452	6.201288	0.789854	0.801278	1.446343
	5.014569	0.794613	0.861400	8.404971	0.814521	0.854521	4.910861	0.714598	0.728901	2.001544
80	5.411220	0.832112	0.864545	2.698788	0.845689	0.865478	2.339985	0.745636	0.756932	1.514948
	5.745976	0.784512	0.805212	2.638582	0.888995	0.904125	1.701921	0.774189	0.789650	1.997057
	4.989858	0.814578	0.845679	3.818173	0.895462	0.925468	3.350895	0.784500	0.806598	2.816826

* % AE = {(Calculated value- Experimental value)/(Experimental value} x 100

CONCLUSION

Dwarf Cavendish shows higher drying rate while comparing the rate of drying amongst all three varieties. Lacatan and Harichal were found to be less effective in drying mechanism. Appearance, colour and texture were improved for two varieties (Dwarf Cavendish and Harichal) at 70 ° C and 80 ° C of drying, while for Lacatan, not much changes were observed. This action could be due to the effect of drying time, different structure and initial moisture content. Initial moisture content in all the three banana varieties decreased to some specific time of blanching. Comparative study of experimental and calculated values of Volume, length and diameter (Table **2**) reveals that as the temperature increases, initial moisture content decreases and shrinkage decreases consequently. Hence, drying time for the material can be automatically reduced. Looking to the characteristics of three different banana varieties, Dwarf Cavendish (from Ankleshwar region, South Gujarat, India) is highly recommended for the commercial production of banana chips as it has proved to be highly attractive in appearance, colour and texture even after long drying. Blanching also added acceptance features to this variety.

NOMENCLATURE

A, B, A', B' A'', B'' Constants in equation (1) – (3)

D & D_o Final and initial diameter of cylindrical banana sample, mm

L & L_o Final and initial length of cylindrical banana sample, mm

V & V_o Final and initial volume of cylindrical banana sample, mm^3

T drying solid temperature, K

X moisture content of drying solid, kg moisture kg dry $solid^{-1}$

X_o initial moisture content of drying solid, kg kg^{-1},dry basis

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The authors confirm that the data supporting the findings of this study are available within the article.

FUNDING

None

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

The authors are grateful to the facilities provided in the mass transfer operations laboratory by the P P Savani University and to the Dean, Dr. Niraj Shah, School of Engineering, P P Savani University for kind support during the research work.

REFERENCES

[1] M.A. Karim, and M.N.A. Hawlader, "Drying characteristics of banana: theoretical modelling and experimental validation", *J. Food Eng.,* vol. 70, pp. 35-45, 2005. [http://dx.doi.org/10.1016/j.jfoodeng.2004.09.010]

[2] V.C. Mariani, A.G.B.D. Lima, and C. Leandro dos Santos, "Apparent thermal diffusivity estimation of the banana during drying using inverse method", *J. Food Eng.,* vol. 85, pp. 569-579, 2008. [http://dx.doi.org/10.1016/j.jfoodeng.2007.08.018]

[3] M-H. Nguyen, and W.E. Price, "Air-drying of banana: Influence of experimental parameters, slab thickness, banana maturity and harvesting season", *J. Food Eng.,* vol. 79, pp. 200-207, 2007. [http://dx.doi.org/10.1016/j.jfoodeng.2006.01.063]

[4] D-W. Sun, and I.W. Eames, "Performance characteristics of HCFC□ 123 ejector refrigeration cycles", *Int. J. Energy Res.,* vol. 20, pp. 871-885, 1996. [http://dx.doi.org/10.1002/(SICI)1099-114X(199610)20:10<871::AID-ER201>3.0.CO;2-4]

[5] K. McDonald, D-W. Sun, and T. Kenny, "The effect of injection level on the quality of a rapid vacuum cooled cooked beef product", *J. Food Eng.,* vol. 47, pp. 139-147, 2001. [http://dx.doi.org/10.1016/S0260-8774(00)00110-2]

[6] E.M. Desmond, T.A. Kenny, and P. Ward, "The effect of injection level and cooling method on the quality of cooked ham joints", *Meat Sci.,* vol. 60, no. 3, pp. 271-277, 2002. [http://dx.doi.org/10.1016/S0309-1740(01)00133-4] [PMID: 22063398]

[7] D-W. Sun, and L. Zheng, "Vacuum cooling technology for the agri-food industry: Past, present and future", *J. Food Eng.,* vol. 77, pp. 203-214, 2006. [http://dx.doi.org/10.1016/j.jfoodeng.2005.06.023]

[8] L. Wang, and D-W. Sun, "Rapid cooling of porous and moisture foods by using vacuum cooling technology", *Trends Food Sci. Technol.,* vol. 12, pp. 174-184, 2001. [http://dx.doi.org/10.1016/S0924-2244(01)00077-2]

[9] S. Janjai, N. Lamlert, P. Intawee, B. Mahayothee, B.K. Bala, M. Nagle, and J. Müller, "Experimental and simulated performance of a PV-ventilated solar greenhouse dryer for drying of peeled longan and banana", *Sol. Energy,* vol. 83, pp. 1550-1565, 2009. [http://dx.doi.org/10.1016/j.solener.2009.05.003]

[10] C. Tunckal, and İ. Doymaz, "Performance analysis and mathematical modelling of banana slices in a heat pump drying system", *Renew. Energy,* 2020. [http://dx.doi.org/10.1016/j.renene.2020.01.040]

[11] L. Wang, and D-W. Sun, "Effect of operating conditions of a vacuum cooler on cooling performance for large cooked meat joints", *J. Food Eng.,* vol. 61, pp. 231-240, 2004. [http://dx.doi.org/10.1016/S0260-8774(03)00095-5]

[12] D-W. Sun, "Solar powered combined ejector-vapour compression cycle for air conditioning and refrigeration", *Energy Convers. Manage.,* vol. 38, pp. 479-491, 1997. [http://dx.doi.org/10.1016/S0196-8904(96)00063-5]

[13] H. Kiani, Z. Zhang, A. Delgado, and D.W. Sun, "Ultrasound assisted nucleation of some liquid and solid model foods during freezing", *Food Res. Int.,* vol. 44, pp. 2915-2921, 2011. [http://dx.doi.org/10.1016/j.foodres.2011.06.051]

[14] H. Kiani, D.W. Sun, A. Delgado, and Z. Zhang, "Investigation of the effect of power ultrasound on the nucleation of water during freezing of agar gel samples in tubing vials", *Ultrason. Sonochem.,* vol. 19, no. 3, pp. 576-581, 2012. [http://dx.doi.org/10.1016/j.ultsonch.2011.10.009] [PMID: 22070859]

[15] J. Ma, H. Pu, D.W. Sun, W. Gao, J.H. Qu, and K.Y. Ma, "Application of Vis–NIR hyperspectral imaging in classification between fresh and frozen-thawed pork Longissimus Dorsi muscles", *Int. J. Refrig.,* vol. 50, pp. 10-18, 2015. [http://dx.doi.org/10.1016/j.ijrefrig.2014.10.024]

[16] J-H. Cheng, D-W. Sun, and H. Pu, "Combining the genetic algorithm and successive projection algorithm for the selection of feature wavelengths to evaluate exudative characteristics in frozen-thawed fish muscle", *Food Chem.,* vol. 197, no. Pt A, pp. 855-863, 2016. [http://dx.doi.org/10.1016/j.foodchem.2015.11.019] [PMID: 26617027]

[17] H. Pu, D.W. Sun, J. Ma, and J.H. Cheng, "Classification of fresh and frozen-thawed pork muscles using visible and near infrared hyperspectral imaging and textural analysis", *Meat Sci.,* vol. 99, pp. 81-88, 2015. [http://dx.doi.org/10.1016/j.meatsci.2014.09.001] [PMID: 25282703]

[18] L. Cheng, D.W. Sun, Z. Zhu, and Z. Zhang, "Emerging techniques for assisting and accelerating food freezing processes: A review of recent research progresses", *Crit. Rev. Food Sci. Nutr.,* vol. 57, no. 4, pp. 769-781, 2017. [http://dx.doi.org/10.1080/10408398.2015.1004569] [PMID: 26115177]

[19] J.P. Mehta, "Improvement of Permeate flux by Laboratory Scale Techniques in Membrane Separation Processes", *Journal of Modern Chemistry & Chemical Technology,* vol. 10, pp. 21-27, 2019.

[20] J.P. Mehta, *Flow Reversal and Pressure pulsation: Innovative technique to enhance flux in Nanofiltration.,* vol. 6. Emerging Trends in Chemical Engineering, 2019, pp. 1-7.

[21] F.A. Fernandes, S. Rodrigues, C.L. Law, and A.S. Mujumdar, "Drying of exotic tropical fruits: a comprehensive review", *Food Bioprocess Technol.,* vol. 4, pp. 163-185, 2011. [http://dx.doi.org/10.1007/s11947-010-0323-7]

[22] D-W. Sun, and J.L. Woods, "The moisture content/relative humidity equilibrium relationship of wheat-A review", *Dry. Technol.,* vol. 11, pp. 1523-1551, 1993. [http://dx.doi.org/10.1080/07373939308916918]

[23] A.E. Delgado, and D-W. Sun, "Desorption isotherms and glass transition temperature for chicken meat", *J. Food Eng.,* vol. 55, pp. 1-8, 2002. [http://dx.doi.org/10.1016/S0260-8774(01)00222-9]

[24] D-W. Sun, "Comparison and selection of EMC/ERH isotherm equations for rice", *J. Stored Prod. Res.,* vol. 35, pp. 249-264, 1999. [http://dx.doi.org/10.1016/S0022-474X(99)00009-0]

[25] Q. Yang, D-W. Sun, and W. Cheng, "Development of simplified models for nondestructive hyperspectral imaging monitoring of TVB-N contents in cured meat during drying process", *J. Food Eng.,* vol. 192, pp. 53-60, 2017. [http://dx.doi.org/10.1016/j.jfoodeng.2016.07.015]

[26] Y-Y. Pu, and D-W. Sun, "Prediction of moisture content uniformity of microwave-vacuum dried mangoes as affected by different shapes using NIR hyperspectral imaging", *Innov. Food Sci. Emerg. Technol.,* vol. 33, pp. 348-356, 2016. [http://dx.doi.org/10.1016/j.ifset.2015.11.003]

[27] J.H. Qu, D.W. Sun, J.H. Cheng, and H. Pu, "Mapping moisture contents in grass carp (Ctenopharyngodon idella) slices under different freeze drying periods by Vis-NIR hyperspectral imaging", *LWT,* vol. 75, pp. 529-536, 2017. [http://dx.doi.org/10.1016/j.lwt.2016.09.024]

[28] J.P. Mehta, T.M. Patel, and K. Nath, "Investigating study on flux enhancement techniques in a Nanofiltration pilot plant–An Experimental overview", *International Journal of Chemical Separation Technology,* vol. 4, pp. 27-34, 2018.

[29] J. Ma, D.W. Sun, J.H. Qu, and H. Pu, "Prediction of textural changes in grass carp fillets as affected by vacuum freeze drying using hyperspectral imaging based on integrated group wavelengths", *Lebensm. Wiss. Technol.,* vol. 82, pp. 377-385, 2017. [http://dx.doi.org/10.1016/j.lwt.2017.04.040]

[30] H. Jiang, M. Zhang, A.S. Mujumdar, and R.X. Lim, "Drying uniformity analysis of pulse-spouted microwave–freeze drying of banana cubes", *Dry. Technol.,* vol. 34, pp. 539-546, 2016. [http://dx.doi.org/10.1080/07373937.2015.1061000]

[31] D. Verma, N. Kaushik, and P. Srinivasa Rao, "Application of high hydrostatic pressure as a pretreatment for osmotic dehydration of banana slices (Musa cavendishii) finish-dried by dehumidified air drying", *Food Bioprocess Technol.,* vol. 7, pp. 1281-1297, 2014. [http://dx.doi.org/10.1007/s11947-013-1124-6]

[32] C. Man, "Y.B., Ammawath, W., Rahman, R.A. and Yusof, S., "Quality characteristics of refined, bleached and deodorized palm olein and banana chips after deep□fat frying", *J. Sci. Food Agric.,* vol. 83, pp. 395-401, 2003. [http://dx.doi.org/10.1002/jsfa.1391]

[33] M.A. Karim, and M.N.A. Hawlader, "Drying characteristics of banana: theoretical modelling and experimental validation", *J. Food Eng.,* vol.

70, pp. 35-45, 2005.
[http://dx.doi.org/10.1016/j.jfoodeng.2004.09.010]

[34] A.B. Lingayat, V.P. Chandramohan, V.R.K. Raju, and V. Meda, "A review on indirect type solar dryers for agricultural crops–Dryer setup, its performance, energy storage and important highlights", *Appl. Energy,* vol. 258, 2020.114005
[http://dx.doi.org/10.1016/j.apenergy.2019.114005]

[35] A.H. Al-Ani, J.S. Antoun, W.M. Thomson, T.R. Merriman, and M. Farella, "Hypodontia: an update on its etiology, classification, and clinical management", *BioMed Res. Int.,* vol. 2017, 2017.9378325
[http://dx.doi.org/10.1155/2017/9378325] [PMID: 28401166]

[36] J.S. Guazi, E.S. Lago□Vanzela, and A.C. Conti□Silva, "Development of smoothies from dehydrated products of strawberry and banana pulps obtained through foam□mat drying", *Int. J. Food Sci. Technol.,* vol. 54, pp. 54-61, 2019.
[http://dx.doi.org/10.1111/ijfs.13900]

[37] M.S. Hatamipour, H.H. Kazemi, A. Nooralivand, and A. Nozarpoor, "Drying characteristics of six varieties of sweet potatoes in different dryers", *Food Bioprod. Process.,* vol. 85, pp. 171-177, 2007.
[http://dx.doi.org/10.1205/fbp07032]