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Airflow Drying Licking Countercurrent of Mango (*Mangifera Indica L*): Experimental Determination of Drying Parameters

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Abstract: This work focused on the experimental determination of drying parameters during airflow drying licking countercurrent of Mangifera Indica L.
The samples were dried in a modular electric dryer operating in forced convection. The data collected made to draw the different drying kinetics of the mango at 40, 50 and 60°C. The solution of the Fick equation and the exploitation of the experimental data by the slope method have used. The values of the mass diffusivity coefficient vary between 1.83*10^{-7} and 2.25*10^{-7} (m²/s), the activation energy E_a = 30.58 kJ/mol and the Arrhenius factor D_0 = 9.74 x 10^{-5} m^2/s.
Keywords: Experimental study, Drying licking, countercurrent, mass diffusivity coefficient, activation energy, mango

I. INTRODUCTION

Mass diffusivity is an important transport parameter for calculating the mass transfer within an agricultural product [1, 2]. When drying mango, [3] have shown that diffusion is the dominant physical mechanism of the drying process of this product. This coefficient largely determines the activity of surface water and partially conditions the quality of the finished product. Whether, it is a drying operation or hydration of foodstuffs, the knowledge of the mass diffusivity is necessary to be able to model the mass transfer process according to the operating conditions.

Thin layer drying kinetics of agricultural products generally exhibit a drying phase at a decreasing rate [4]. During this phase, it is no longer the external conditions of temperature and relative humidity of the drying air which manage the drying process, but it is the mode of water transfer from the breast of the product towards its surface, manages and controls this kinetics. This mode of transfer, which strongly depends on the type of product, its structure and especially its moisture, reflects the mechanisms driving the transport of moisture.

The mass diffusion coefficient is generally identified using drying kinetics, by analytical resolution or numerical resolution of the diffusion equation. The analytical method assumes a constant diffusion coefficient and moisture on surface that is instantly equal to its equilibrium value. In addition, the withdrawal of the product is not taken into account. Difficulties related to the modeling of the water transport phenomenon during a drying process led most researchers to limit themselves to a modeling represented by the diffusion equation (second law of Fick), introducing a coefficient mass diffusivity which includes the effects corresponding to all the phenomena that can cause the migration of water. The mass diffusivity coefficient is obtained by exploiting experimental results of the drying kinetics [5, 6].

Some studies show that the experimental methods most commonly used to determine the diffusivity coefficient are based on drying techniques [7, 8]. This diffusivity varies with the water content of the product and is determined from the slopes of the curves reflecting experimental drying kinetics. Several authors have used the slope method to determine the effective diffusivity coefficient: [9] on green beans, [10] on okro, [11, 12] on tomato, [13] on marjoram leaves, [14] on cocoa, [15] on the Iroko. Knowledge of the mass diffusion coefficient of biological materials makes it possible to estimate their drying times while giving possibilities of optimizing energy consumption during drying.

Thus, for the purpose of optimizing drying, works of [16] have shown that airflow drying licking countercurrent is also adjusted by one of the thin film drying models, encountered in the literature. The present work aims to complete this optimization of drying, by the experimental determination of the diffusion coefficient and the activation energy for this drying mode. It will be a question of showing the influence of the drying air temperature on the diffusion coefficient.

II. MATERIAL AND METHODS

A. Plant Material

The mangoes used in this study were purchased from the markets of the town of Dang-Ngaoundere (latitude: 7° 32 N and longitude: 13° 58 E) in the Adamawa Region of Cameroon. The mango had an average weight of 310 ± 45 g, an average moisture of 84 ± 2%. Its large width measured between 6.4 and 7.5 cm and its height between 8.20 and 11.60 cm. Yellowish in color, these mangoes are harvested between April and June [17]. They were transported and stored at the laboratory of Energetic and Applied Thermal at the National School of Agro-Industrial Sciences of Ngaoundere, to be brought to the ambient temperature of the laboratory for the duration of the tests.

B. Experimental Device and Protocol

The experimental device is an electric forced convection dryer. In the airflow drying pattern licking countercurrent, the ventilated hot air passes through the drying chamber from bottom to top. It was presented by [16] as well as the experimental protocol.

C. Calculation of Diffusivity

Experimental data for the determination of effective diffusivity are calculated using the second Fick diffusive model, which is widely used to describe the drying process for most biological products [4].

$$\frac{\partial M}{\partial t} = D_{eff}\left(\frac{\partial^2 M}{\partial x^2}\right) \qquad (1)$$

Taking into account the assumptions that the water migration is only diffusion, the shrinkage is negligible, the product is in the form of wafer, the drying time is long, the coefficient of diffusivity and the temperature are constant, the solutions of equation (1) for thin layer are given by the expression (2) [18]:

$$MR = \frac{M-M_e}{M_0-M_e} = \frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n-1)^2}\exp\left(-\frac{(2n-1)^2\pi^2 D_{eff}t}{4L^2}\right) \qquad (2)$$

In practice, by simplification, only the first term of equation (2) is used.

$$MR = \frac{8}{\pi^2}\exp\left(-\frac{\pi^2 D_{eff}t}{4L^2}\right) \qquad (3)$$

The effective diffusivity is calculated using the slope of equation (3), that is to say when the curve corresponding to the logarithm of MR is plotted against time, a line with a slope K is obtained:

$$\ln(MR) = \ln\left(\frac{8}{\pi^2}\right) - \pi^2\frac{D_{eff}t}{4L^2} \qquad (4)$$

$$K = \frac{\pi^2 D_{eff}}{4L^2} \qquad (5)$$

D. Calculation of the Activation Energy

The dependence of the diffusivity coefficient (D_{eff}) on the temperature is often described by the Arrhenius type equation given by the following expression [19]:

$$D_{eff} = D_0\exp\left(-\frac{E_a}{R(T+273{,}15)}\right) \qquad (6)$$

The activation energy (E_a) is calculated from the slope of equation (6); that is, when the curve corresponding to the logarithm of D_{eff} is plotted against the inverse of the temperature (1/T), a line with a slope is obtained.

III. RESULTS AND DISCUSSION

A. Kinetics of Drying

The curves below show the evolutions of the moisture ratio as a function of time and the position of the product inside the drying chamber.

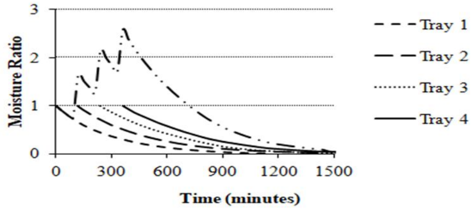

Figure 1. Moisture ratio profiles of mango as a function of time for different positions of trays for a temperature of 40°C.

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The curves of Figure 1 show the drying kinetics as a function of time at 40°C. These kinetics have the same pace, but the products on the trays do not reach their equilibrium moisture at the same time. The tray 1 reaches its equilibrium moisture faster than the tray 2, and so on. The curve (sum 40°C) represents the sum of the moisture ratio of all the trays. The peaks of the latter illustrate the entries of the different trays inside the drying chamber.

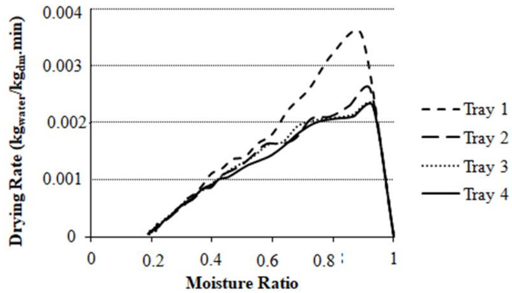


Figure 2. Drying rate as a function of the Moisture ratio to 50°C

The curves of Figure 2 show that the drying rate profile increases at the beginning of drying and after a certain moisture value of each tray, it decreases only. It is found that the drying rate is higher in the first tray compared to the other screens up to a moisture ratio of 0.6. Below this last value, the difference between the curves becomes very small and tend to be similarly at the end of drying. On the other hand, it can also be seen that the drying rate decreases as a function of the moisture and as a function of the position of the screen relative to the heat source. Similar results were obtained by [19-21].

B. Effective Diffusivity

In figure 3, the effective diffusivities of mango were evaluated by determining the slopes of the curves of ln (MR) as a function of time for three different temperatures.

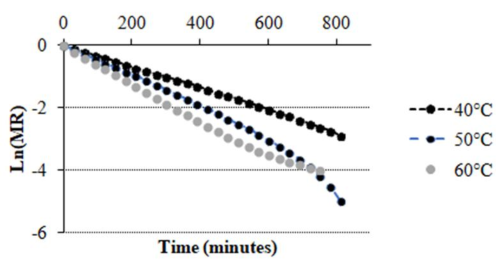


Figure 3. The Arrhenius relationship between the effective diffusivities and temperature

The effective diffusivity coefficient increases during the drying process as the temperature of the product increases. The values of the effective diffusivity coefficients vary between 1.83 x 10^{-7} and 2.25 x 10^{-7} m²/s. These results are consistent with those obtained by [22-24].

Figure 4 shows that the mass diffusivity coefficient decreases as the position of the product shelf increases. This leads us to say that it is not constant along the drying chamber.

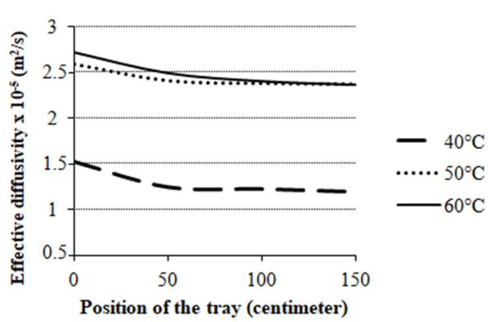


Figure 4. Evolution of the effective diffusivity according to the position of the product in the dryer for different temperatures

It decreases as you move away from the heat source. It is even more important in the first tray than in the last tray. It tends to become constant towards the last position of the product tray in the drying chamber.

Each of the curves of the effective diffusivity coefficient during the drying of the mango made to obtain an equation in the form of a polynomial of second degree (equation 8) whose values of the coefficients are given in table 1.

$$D_{eff} = ax^2 + bx + c \quad (m^2/s) \quad (8)$$

Where x is the position of the product tray

Table 1. Model coefficients values

Temperature (°C)	a	b	c	R^2
40	2.10^{-10}	-6.10^{-8}	2.10^{-5}	0.97
50	2.10^{-10}	-5.10^{-8}	3.10^{-5}	0.98
60	2.10^{-10}	-4.10^{-8}	3.10^{-5}	0.99

C. Activation Energy

The figure below shows the curve of Ln (D_{eff}) as a function of the inverse temperature (1/T). This curve is plotted from the values obtained from the effective diffusivity for different temperatures, to evaluate the activation energy.

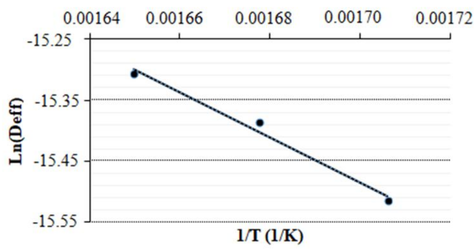


Figure 5. Evolution of Ln (D_{eff}) as a function of 1/T for different temperatures.

The value of the activation energy is 30.58 kJ / mol calculated from the slope of Figure 5. The Arrhenius factor is $D_0 = 9.74 \times 10^{-5}$ m^2/s. Some values of activation energy obtained by researchers for different tropical products are presented in Table 2.

Table 2. Values of the activation energy of some agricultural products

Product		Activation energy Ea (kJ/mol)	Product		Activation energy Ea (kJ/mol)
Carrots	[20]	28.36	Cocoa	[14]	44.92
Tomato	[11]	32.94	Marjoram leaves	[13]	82.00
Tomato	[12]	34.71	Okro	[10]	779.00
Red pepper	[22]	41.95	Mango	[24]	16.86 - 31.51
Present work (Mango)					30.58

From the results it is realized that a small activation energy value is obtained, which is a consequence on the reduction of the drying time. This allows us to conclude that the drying licking countercurrent conduct to the good results.

IV. CONCLUSION

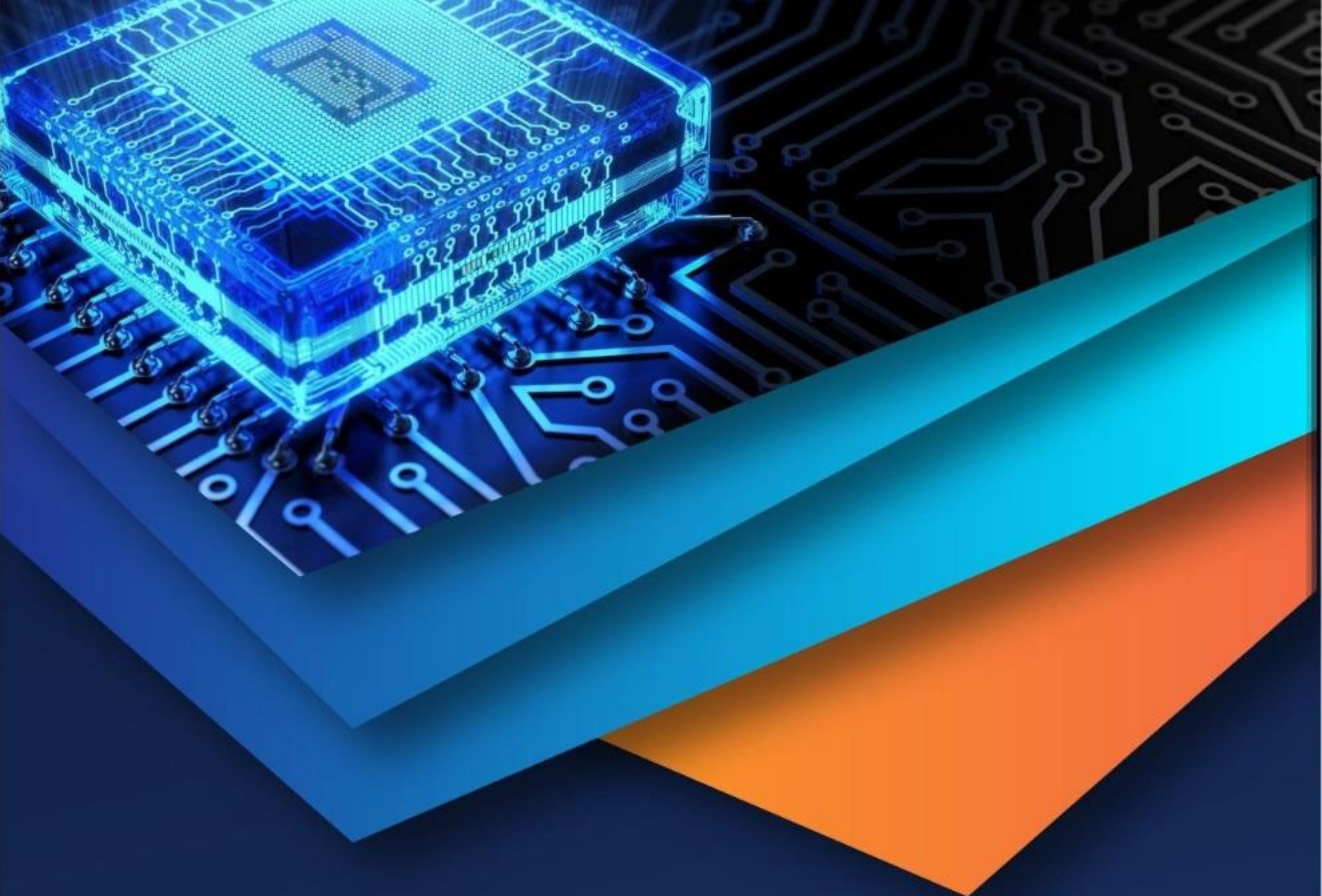
In this work, the effective diffusivity during the airflow drying licking countercurrent of mango has been estimated experimentally. The curves of the diffusivity coefficient during this process have permitted to obtain an equation in the form of a second-degree polynomial. The Arrhenius equation yielded the value of the activation energy. The main results showed that the effective diffusion coefficient increases during the drying process with the increase of the temperature, on the other hand it decreases with the increase of the position of the product tray. Thus, the values of the effective diffusivity coefficient calculated for the three temperatures are in agreement with the literature and vary between 1.83×10^{-7} and 2.25×10^{-7} m^2/s. The activation energy E_a = 30.58 kJ/mol.

A. Nomenclature

D_{eff} : Effective moisture diffusivity (m^2 /s),
M: One-time moisture
D_0: Diffusivity coefficient at infinite temperatures ($m^{2/}s$)
Me: Equilibrium moisture
Ea: Activation energy (kJ/mol)
M_0: One-time water content
L: Half of the thickness of the slice (m)
K: Drying constant
t: Time
T: Drying air temperature (°C)
MR: Moisture Ratio
n: Positive integer
x: Direction (m)
R: gaze constant

REFERENCES

[1] L. Hassini, S. Azzouz, and A. Belghith, "Estimation of the moisture diffusion coefficient of potato during hot-air drying." pp. 1488-1495.
[2] A. O. Dissa, H. Desmorieux, J. Bathiebo, and J. Koulidiati, "Convective drying characteristics of Amelie mango (Mangifera Indica L. cv. 'Amelie') with correction for shrinkage," Journal of Food Engineering, vol. 88, no. 4, pp. 429-437, 2008/10/01/, 2008.
[3] A. O. Dissa, H. Desmorieux, A. Almeck, J. Bathiebo, and J. Koulidiati, "Drying of "Amelie" mango (Mangifera Indica L.): Influence of temperature on drying rates and shrinkage curves from 50 to 90 C," J. Soc. Ouest-Afr. Chim, vol. 29, pp. 55-65, 2010.
[4] D. Fahloul, F. Benmadi, and S. Boudraa, "Estimation de la diffusivité massique et cinétique de séchage sous vide de la pomme de terre (variété Spunta)," Revue des Energies Renouvelables, vol. 12, no. 4, pp. 655-665, 2009.
[5] M. Queiroz, and S. Nebra, "Theoretical and experimental analysis of the drying kinetics of bananas," Journal of food Engineering, vol. 47, no. 2, pp. 127-132, 2001.
[6] S. Erenturk, M. S. Gulaboglu, and S. Gultekin, "Experimental determination of effective moisture diffusivities of whole- and cut-rosehips in convective drying," Food and Bioproducts Processing, vol. 88, no. 2, pp. 99-104, 2010/06/01/, 2010.
[7] W. McMinn, and T. Magee, "Principles, methods and applications of the convective drying of foodstuffs," Food and Bioproducts Processing, vol. 77, no. 3, pp. 175-193, 1999.
[8] P. B. Pathare, and G. P. Sharma, "Effective Moisture Diffusivity of Onion Slices undergoing Infrared Convective Drying," Biosystems Engineering, vol. 93, no. 3, pp. 285-291, 2006/03/01/, 2006.
[9] İ. Doymaz, "Drying behaviour of green beans," Journal of Food Engineering, vol. 69, no. 2, pp. 161-165, 2005/07/01/, 2005.
[10] A. Kuitche, M. Edoun, and G. Takamte, "Influence of pre-treatment on drying on the drying kinetic of a local okro (Hibiscus ersculentus) variety," World J. Dairy Food Sci, vol. 2, no. 2, pp. 83-88, 2007.
[11] İ. Doymaz, "Air-drying characteristics of tomatoes," Journal of Food Engineering, vol. 78, no. 4, pp. 1291-1297, 2007/02/01/, 2007.
[12] S. BOUGHALI, "Etude et optimisation du séchage solaire des Produits agro-alimentaires dans les zones Arides et désertiques," Université de Batna 2, 2010.
[13] A. Benhamou, A. Idlimam, A. Lamharrar, B. Benyoucef, and M. Kouhila, "Diffusivité hydrique et cinétique de séchage solaire en convection forcée des feuilles de marjolaine," Revue des Energies renouvelables, vol. 11, no. 1, pp. 75-85, 2008.
[14] C. L. Hii, C. L. Law, and M. Cloke, "Modeling using a new thin layer drying model and product quality of cocoa," Journal of Food Engineering, vol. 90, no. 2, pp. 191-198, 2009/01/01/, 2009.
[15] M. Louisa, A. O. L. Maxa, C. N. Adelineb, and M. A. Florentb, "Determination of the diffusion coefficient and the activation energy of water desorption in IROKO wood (Chlorophora excelsa), during a conductive drying," 2013.
[16] R. Ekani, Yannick, F. Tetang, Abraham, M. Edoun, and A. Kuitche, "Experimental Study of the Drying Kinetics of Mango (mangifera indica L.) during Airflow Drying Licking Countercurrent," American Journal of Food Science and Technology, vol. 7, no. 4, pp. 127-132, 2019.
[17] F. A. Tetang, M. Edoun, A. Kuitche, and B. Zeghmati, "Experimental drying kinetics of mango slices (Mangifera indica L.) Amelie under intermittent conditions," International Journal of Thermal Technologies, vol. 6, no. 3, pp. 203-211, 2016.
[18] İ. Doymaz, "The kinetics of forced convective air-drying of pumpkin slices," Journal of Food Engineering, vol. 79, no. 1, pp. 243-248, 2007/03/01/, 2007.
[19] Z. Wang, J. Sun, X. Liao, F. Chen, G. Zhao, J. Wu, and X. Hu, "Mathematical modeling on hot air drying of thin layer apple pomace," Food Research International, vol. 40, no. 1, pp. 39-46, 2007/01/01/, 2007.
[20] I. Doymaz, "Convective air drying characteristics of thin layer carrots," Journal of food engineering, vol. 61, no. 3, pp. 359-364, 2004.
[21] B. Touati, "Etude théorique et expérimentale du séchage solaire des feuilles de la menthe verte (Mentha viridis)," Lyon, INSA, 2008.
[22] P. Gupta, J. Ahmed, U. Shivhare, and G. Raghavan, "Drying characteristics of red chilli," Drying technology, vol. 20, no. 10, pp. 1975-1987, 2002.
[23] A. Maskan, S. Kaya, and M. Maskan, "Hot air and sun drying of grape leather (pestil)," Journal of Food Engineering, vol. 54, no. 1, pp. 81-88, 2002/08/01/, 2002.
[24] M. Edoun, B. Matuam, and A. Kuitche, "Mathematical Modelling of Thin Layer Mangoes (Mangifera indica L.) Drying. Process," International Journal of Current, 2014.



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