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RESEARCH ARTICLE

STUDY AND MODELING OF THE KINETICS OF *DIOSCOREA CAYENENSIS* DRYING, *COLOCASIA ESCULENTA* AND *IPOMOEA BATATAS* LAM OF ORIGIN CONGOLAISE

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ABSTRACT

The objective of this work is to contribute to the study of starch products in particular Dioscorea cayenensis, Colocasia esculenta and Ipomoea batatas by the characterization and the modeling of their kinetics of convectif drying to the drying oven. The convectif drying of the samples of thickness 4 and 14 mm was carried out at temperatures of 50, 60 and 70 °C. The modeling of the kinetics of drying was carried out with the model of Henderson and Pabbis, the model of Page, the model of Newton and the model of Midilli. The results obtained show that the kinetics of drying of Dioscorea cayenensis, Colocasia esculenta and Ipomoea batatas present two (02) phases. It is of the phase of temperature setting and the phase at decreasing speed. The reduction the thickness of the product from 14 to 4 mm makes it possible to lower the energy barrier (energy of activation) from 19.43 to 10.68 kJ. mol^{-1} from 35.33 to 11.52 kJ. mol^{-1} and from 11.08 to 5.77 kJ. mol^{-1} respectively during the drying of Dioscorea cayenensis (DC), Colocasia esculenta (EC) and Ipomoea batatas(IB). Conversely, the increase the thickness from 4 to 14 mm raises the coefficients of effective diffusion of 8.0 2 $\times 10^{-10}$ with 3.14×10^{-9} $m^2 s^{-1}$(DC.), of $4.38\times 10^{-8}$with $2.78\times 10^{-7} m^2 s^{-1}$ (EC) and of 1.29×10^{-7} with $9.53\times 10^{-7} m^2 s^{-1}$ (IB) during drying with 70°C. Among does the four (04) models tested, the model of Midilli describe better the kinetics of drying of these three starch products some is the species with the values of coefficient of determination (R^2) reduced ki-square (χ^2) and the square root of the average error quadratic (RMSE) which vary respectively from 0.99921 = R^2 = 0.99952 of 0.000029 = χ^2= 0.0 00071 and of 0.00662 = RMSE = 0.00840.

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INTRODUCTION

In sub-Saharan Africa in general and Republic of Congo in particular, the roots and tubers constitute the most significant food cultures. These local roots and tubers are mainly the manioc (*Manihot esculenta,* the potato (*Solanum tuberosum,* the sweet potato (*Ipomoea batatas)* the yam (*Dioscorea* and the taro (*Colocasia esculenta).* The industrial potential these starch products was studied in under area because their very high contents of glucides (60-90% glucides in base dries mainly in the form of starch) (Nepa, 2006 Njintang, 2003 Payne *and Al,* 1941) It arises that the flours and the starches of these products can beings used like alternative in agricultural processing industry and pharmaceutical industry while replacing or in substituent cereals (Ganongo-Po *et al.,* 2018; Ndangui, 2015; Ndangui *et al.,* 2014; Ahmed *et al.,* 2010; Kouassi, 2009). The transformation of the roots and tubers into flours requires a process of drying inclusively, because, they are very perishable because of their water content high. Drying constitutes one of the complex processes where intervene of the phenomena of transfers of heat and matter in a simultaneous way. During drying, water is eliminated from the solid, reducing the growth potential of the micro-organisms and the undesirable chemical reactions therefore increase in the lifespan of product (Gowen *et al.,* 2008). The maitrise of the drying of the starch products becomes paramount for the development and of the industrialization of their processes of transformation. It carried out thanks to modeling. A great number of mechanisms were proposed to explain the movement of water inside food during drying (Prati, 1990). Models of various complexities were developed to describe the phenomenon of drying. They were classified in three principal categories: ideal models, semi models empirical or phenomenologic and models empirical (Midilli *et al.*, 2002; Panchariya *et al.*, 2002). The ideal models according to their complexity, detail the mechanisms of transfer finely. Unfortunately, the difficulty of obtaining certain parameters limits sometimes their use. In the current state of knowledge, the establishment of the majority of the models of kinetics of

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drying of various products comes under the field semi-empirical (Guimaraes *and al.,* 2018; Nasfi and Bagane, 2017; Nogbou *and Al,* 2015; Thu ha Nguyen., 2015; Messaoudi *and Al* 2015; Jannot *and Al,* 2006).

MATERIELS AND METHODS

Vegetable material and sampling

The tubers of *Dioscorea cayenensis* (yellow yam) of *Colocasia esculenta* (taro) and *Ipomoea batatas* (sweet potato were bought at the Total market of Brazzaville. They were stored at the laboratory at the ambient temperature for all the period of the experiment. The tubers of these three products were dimensioned in the parallelepipedic form (L×l×E = 40 mm× 30 mm × (4 or 14 mm)). Dimensioning was carried out using an electric Slicer of mark RCL1. Exact dimensions were checked using a slide caliper and / or scale.

The samples were coded in the following way: X-P/Y/Z
With:

X: Code of starch product: *Dioscorea cayenensis* (cd.); *Colocasia esculenta* (EC) and *Ipomoea batatas* (IB)
P: Code parallelepipedic form
Y: Code thickness (mm)
Z: Code temperature of drying (°C)

Drying with the drying oven

The drying of the plates of each starch product was carried out at temperatures of 50, 60 and 70°C. the sample of each product was placed at drying oven (INDELAB; 0-250°C), then weighed after each five minutes (300 S). Using a balance with precision of mark EXPLORER-PRO (0-210g, with E = 0.0001g), the mass of the each sample was followed in the course of time until this one does not vary any more between 3 successive measurements.

Parameters of kinetics of drying

Water content: The determination of the water content was carried out according to method AOAC (1990) based to the measure of the loss in mass of the samples after stoving with 105 ± 2 °C until complete elimination of interstitial water and the volatile matters.

$$X = [(m_h - m_s / m_h] \times 100 \quad (1)$$

X: water content;
m_h : mass wet sample (g);
m_s : mass dry sample (g);

Speed of drying: The instantaneous speed of drying at time T is determined by the formula below:

$$dX/dt = -[(X_{(t+\Delta t)} - X_{(t)}) / \Delta t] \times 100 \quad (2)$$

Avec :
dX/dt : speed of drying ($g_{H2O}\ g^{-1}_{MS}\ s^{-1}$)
X : water content in base dries ($g_{H2O}\ g^{-1}_{MS}$).
Δt : variation of time in seconds (s)

Effective diffusivity (D_{eff})

The transfer of matter during drying is controlled by internal diffusion. The second law of Fick of diffusion indicated in the equation (2), was largely used to describe the process of drying for the majority of the biological products (Srikiatden, *et al.*, 2008. The coefficient of diffusion of the plates of yam was given starting from the analytical equation of the second law of Fick, developed by Crank (1975). By supposing that the transfers are unidimensional, water content initially uniform in the product, without contraction of the solid matter and a long time of diffusion. The analytical solution of the equation of Fick, according to the parallelepipedic shape of the sample is given by the following equation

$$X^* = (X_{(t)} - X_{eq}) / (X_o - X_{eq}) = 8/(\pi)^2 \exp[(\pi^2 \times D_{eff} / 4L^2) \times t] \quad (3)$$

X* : water content reduced
$X_{(t)}$:($g_{H2O}.g^{-1}._{MS}$) : water content instantaneous ;
X_o : ($g_{H2O}.\ g^{-1}._{MS}$) : water content initial ;
$X_{éq}$: ($g_{H2O}.g^{-1}._{MS}$) : water content with balance;
D_{eff} (m^2s^{-1}) : coefficient of effective diffusion ;
L (m) : half-thickness of the sample ;
t (s): time of drying.

The water content reduced was simplified by the equation (Equation 4) because Xeq is relatively negligible compared to $X_{(t)}$ and X_O (Akmel *et al.,* 2009; Haoua, 2007).

The water content reduced was simplified by the equation (Equation 4) because Xéq is relatively negligible compared to $X_{(t)}$ and X_O (Akmel *et al.,* 2009; Haoua, 2007).

The equation (3) becomes:

$$(X^*) = X_{(t)} / X_o = \mathrm{Ln}\,(8/\pi^2) - [(\pi^2 \times D_{eff} \times t) / 4L^2] \quad (4)$$

The coefficient of diffusion is thus calculated starting from the bearing graph in X-coordinate the time of drying and in ordinate Ln X *. The slope of the straight regression line giving ln X * according to time makes it possible to calculate the coefficient of diffusion of moisture according to the following relation:

$$(\pi^2 \times D_{eff})/4L^2 = K \longrightarrow D_{eff} = (4L^2 \times K)/\pi^2 \text{ with K : slope} \quad (5)$$

Energy of activation

The energy of activation it is the energy which it is necessary to start the mass phenomenon of diffusion in the agricultural produce (Sacilik, 2007). The coefficient of effective diffusion (Deff) is corolla at the temperature of drying starting from the following equation of Arrhenius (Doymaz and Mehmet, 2002). Indeed, this function ln(D_{eff})= f (1/T) is linear whose slope is equal the opposite one of the energy of activation on the constant of perfect gases.

$$D_{eff} = D_0 \exp(-E_a/RT) \text{ ou } \mathrm{Ln}\,(D_{eff}) = \mathrm{Ln}(D_0) - (E_a/R) \times (1/T) \quad (6)$$

The energy of activation is calculated starting from the slope of the graph Ln (D_{eff}) according to (1/T); one obtains a line of equation Y' = K_0 ' ×t + B'

$$K_0' = E_a/R \longrightarrow E_a = K_0' \times R \quad (7)$$

D_{eff} : coefficient of diffusion (m^2s^{-1})
D_0 : parameter of diffusion of Arrhenius (m^2s^{-2}),

E_a : energy of activation or energy barrier to cross before evaporation is effective ($J.\ mol^{-1}$)
T : temperature of drying (K)
R : constant of perfect gases (8,314 $J.\ mol^{-1}\ K^{-1}$).

Modeling of the kinetics of convectif drying

Several semi-empirical mathematical models were proposed in the literature to describe the process of drying. For reasons of good adjustment of the experimental data and their facility to determine the coefficients, they are largely employed in work of drying, particularly in the description of the water reaction of in the product (Murthy and Manohar, 2012; Hii *et al.*, 2008). Four (04) mathematical models of drying in thin layer (tableau1 were used to describe the behaviour of the drying of these three starch products. The modeling of the kinetics was carried out using the Software Origin Pro 2016

The choice of the best model is based on the values of the coefficient of determination (R^2 high and of reduced ki-square (χ^2) and of the square root of the average quadratic error (RMSE) lowest (Doymaz., 2004)
These parameters were calculated as follows:

$$R^2=1-[\Sigma^N_{i=1}(X^*_{ei}-X^*_{pi})^2]/\Sigma^N_{i=1}(X^*_m-X^*_{pi})^2] \quad (8)$$

$$RMSE=[(1/N)\times\Sigma^N_{i=1}(X^*_{ei}-X^*_{pi})^2]^{½} \quad (9)$$

$$\chi^2=1/(N-n)\times\Sigma^N_{i=1}(X^*_{ei}-X^*_{pi})^2 \quad (10)$$

with
$X^*_{e,\ i}$: water content reduced experimental for *i eme* observation ;
$X^*_{p,\ i}$: water content reduced predicted for *i eme* observation ;
X^*_m : average of the experimental values;
N: a number of observations;
n: a number of constants of the model;

RESULTS AND DISCUSSION

Effect of the temperature on the kinetics of drying of three starch products

The effect of the temperature during convectif drying of 50 to 70°C of the samples of the parallelepipedic shape thickness E=14 mm of three starch products is presented on Fig.1a, Fig.1b and Fig. 1c. For each product, the curves of kinetics decrease according to time and of the water content until stability. The curves take a decreasing exponential form (Fig.1a) The rise in the temperature to the drying oven increases the speed of water evaporation (Fig.1b and Fig. 1ç) They are evolve/move of 1.251×10^{-5} with 2.869×10^{-5} $g_{H2O}.\ g^{-1}$ $MS.s^{-1}$ (*Dioscorea cayenensis* (DC)), of 8.114×10^{-5} with 1.134×10^{-4} $g_{H2O}.g^{-1}{}_{MS}.s^{-1}$ (*Colocasia esculenta* (EC)) and of 4.1571×10^{-5} to 3.327×10^{-5} $g_{H2O}.g^{-1}{}_{MS}.s^{-1}$ (*Ipomoea batatas* (IB)) during the first 5 minutes when the temperature passes from 50°C to 70°C. The rise in the temperature of drying has by consequence the reduction of the time of drying of the samples (Fig.1a). Thus, times necessary to reach a residual moisture of X * = 5% by increasing the temperature increase by 50 to 70°C are 26 700 to 22 880s, 21 900 to 14 400s and 21 000 to 14 700s respectively for drying *Dioscorea cayenensis* (DC), *Colocasia esculenta* (EC) and *Ipomoea batatas* (IB).

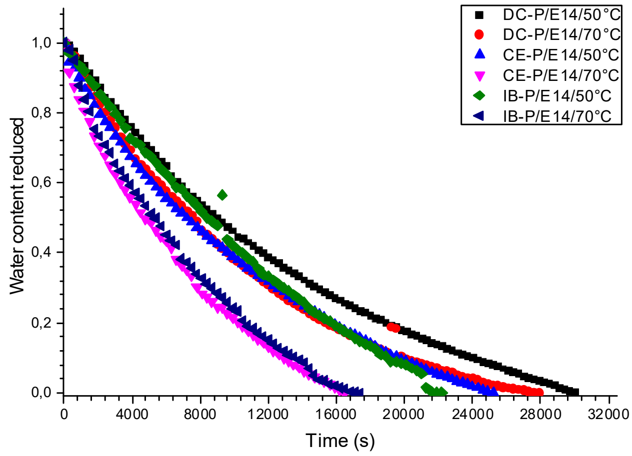

Fig. 1a.

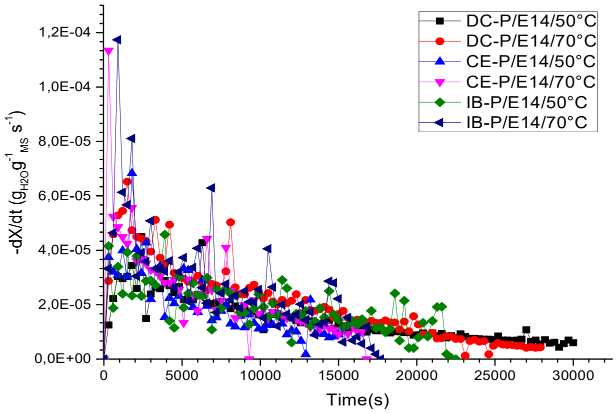

Fig. 1a.

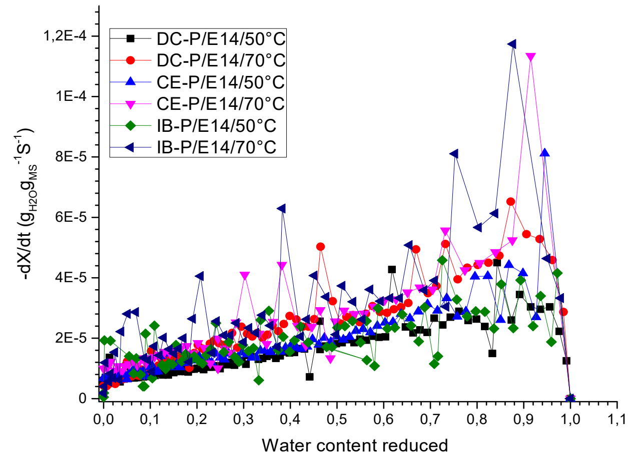

Fig. 1a.

Fig.1 (a, b, c). Effect of the temperature on the kinetics of drying of three starch products (E=14 mm)

This reduction in the time of drying is about 14.61 % (DC), of 34.25 % (EC) and 30 % (IB). Indeed, this influence of the temperature on the speed of evaporation is due to the contribution of heat to the product, which believes with the rise in the temperature. The reduction speed according to time (Fig.1b) and water content reduced (Fig.c) is primarily due to the instantaneous reduction in the availability out of water. And consequently, the exchanges are done with difficulty. The kinetics of drying of three products proceed in two (02) phases. It is acted of a phase of temperature setting relatively short, of a phase at constant speed and as end of a phase at decreasing speed (Fig.1b; Fig.c) The phase at constant speed is not always identifiable, same for the crop product with strong water content initial by the fact of the absence of an interstitial water film because of the cellular walls which disturb the migration of moisture (Bonnazi and Bimbenet, 2003). The absence of the phase at constant speed during drying was also highlighted by several authors for foodstuffs and biological at the time convectif drying (Mujumdar, 2006; Bonazzi and Bimbenet, 2003; Van Brakel, 1980). The effect of the temperature on the kinetics of drying was deferred by several authors in the literature (Menasra and Fahloul, 2015; Arslan and Musa Ozcan, 2007; Locin, 1961) These authors noted that the time of drying decreases with the increase in the temperature.

Effective Diffusivity

The influence thickness of the samples and the temperature of drying on the coefficient of effective diffusion of three starch-based is presented on Table 2. The results obtained show that the variation the thickness of the samples of three starch-based from 4 to 14 mm and of the temperature of convectif drying of 50 to 70°C, has an effect on the increase of the coefficient of diffusion. The coefficients of diffusion respectively vary from 4.75×10^{-10} with 3.14×10^{-9} m^2 s^{-1} for *Dioscorea cayenensis* (DC.), from 3.41×10^{-8} with 2.78×10^{-7} m^2 s^{-1} for *Colocasia esculenta* (EC) and from 8.92×10^{-8} with 9.53×10^{-7} m^2 s^{-1} for *Ipomoea batatas* (IB). It is also noted that the increase thickness of the samples generates an increase in diffusivity. The effect the thickness would be due to the increase in the heat-transferring surface between the product and the environment of drying. The coefficients of effective diffusion vary from one product to another. At illustrative title, the samples thickness E = 4 mm, dried with 70°C respectively present the coefficients of 8.02×10^{10} m^2 s^{-1} (DC) of 4.38×10^{-8} m^2 s^{-1} (EC) and 1.29×10^{-7} m^2 s^{-1} (IB). The variation of coefficient of diffusion between the two thicknesses (4 and 14 mm) for each product is primarily related to the side diffusion. Indeed, for the thick samples, the side diffusion is taken into account. These results are in agreement with those found in the literature (Boughali *et al.*, 2008; Nguyen and Price 2007; Doymaz, 200â). The effect of the temperature of drying on the coefficient of diffusion on the one hand and the thickness of cutting in plates on the other hand are in agreement with those obtained by Messaoudi et *al.,*2015; Zielinska and Markowski, 2010; Aghfir *et al.,* 2008; Park et *al.,* 2002.

Energy of activation

Energies of activation of the various samples of the three starch-based the sweet potato were given graphically starting from the equation of Arrhenius (Fig.2). Energies of activation of the reaction of evaporation during the drying of *Dioscorea cayenensis, Colocasia esculenta and Ipomoea batatas* are presented in Table 3. They are about 11.52 to 35.33 $kJ.mol^{-1}$ from 10.68 to 19.43 $kJ.mol^{-1}$ and 5.77 to 11.08 $kJ.mol^{-1}$ of for and respectively for the drying of *Dioscorea cayenensis, Colocasia esculenta* and *Ipomoea batatas.* It is also noted that the values of energy of activation strongly depend with the matrix on the product to dry. For each product, one notes that the energy of activation believes with the increase thickness of the samples. The larger the sample is, the more the quantity of energy necessary to start the reaction of evaporation is large.

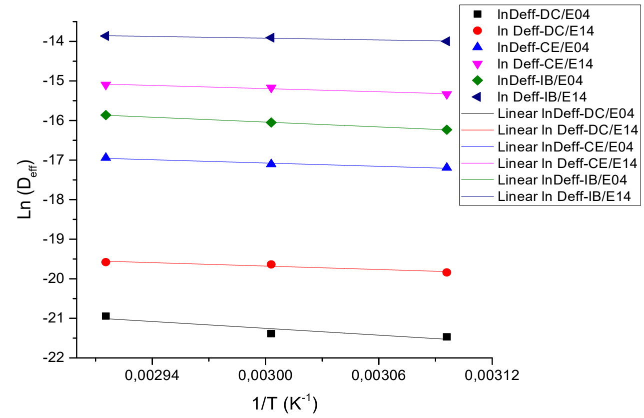

Fig. 2. Law of Arrhenius applied to the drying of three starch products

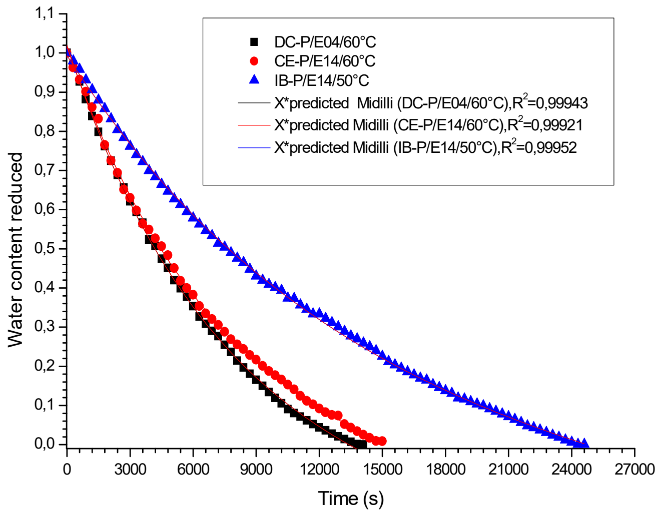

Fig. 3. Simulation of the kinetics of convective drying of three starch products by the model of Midilli

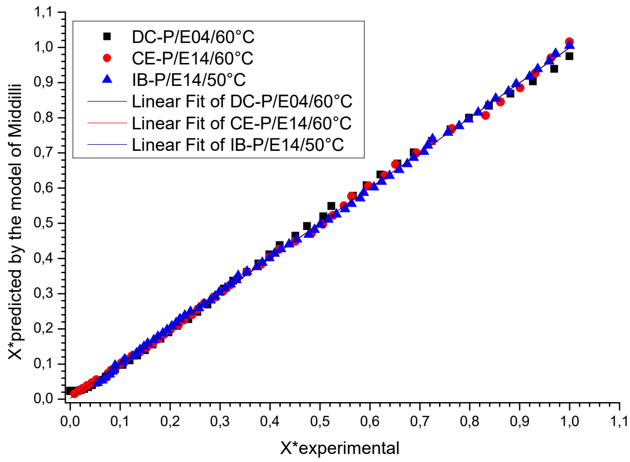

Fig. 4. Valeurs predicted by the model of Midilli according to experimental values of various samples

For the various products, the energy of activation varies from one product to another with the operating conditions. The reduction in the energy of activation with the thickness of the product was also made by Messaoudi and Fahloul, 2015. By comparing the results obtained with those of the literature (Table 2), one notes that energies of activation of *Ipomoea batatas* weak, are followed those of *Dioscorea cayenensis* and at the end *of Colosasia esculenta.*

Table 1. Mathematical models used

N°	Name of the model	Expression of the model	References
1	Newton	X*= exp(-kt)	Doymaz, 2004 a
2	Henderson &Pabis	X*= a.exp(-kt)	Akmel *et al*., 2009
3	Page	X*= exp(-k t^n)	Sharma et Prasad ,2001
4	Midilli	X*= a exp(-kt)+ bt	Midilli *et al*., 2002

Table 2. Effective diffusivity of three starch products

Dioscorea cayenensis		*Colocasia esculenta*		*Ipomoea batatas*	
Samples	D_{eff} ($m^2.s^{-1}$)	Samples	D_{eff} ($m^2.s^{-1}$)	Samples	D_{eff} ($m^2.s^{-1}$)
DC/E04/50°C	4.75×10^{-10}	CE/E04/50°C	3.41×10^{-8}	IB/E04/50°C	8.92×10^{-8}
DC/E14/50°C	2.42×10^{-9}	CE/E14/50°C	2.190×10^{-7}	IB/E14/50°C	8.34×10^{-7}
DC/E04/60°C	5.15×10^{-10}	CE/E04/60°C	3.73×10^{-8}	IB/E04/60°C	1.069×10^{-7}
DC/E14/60°C	2.96×10^{-9}	CE/E14/60°C	2.584×10^{-7}	IB/E14/60°C	9.135×10^{-7}
DC/E04/70°C	8.02×10^{-10}	CE/E04/70°C	4.38×10^{-8}	IB/E04/70°C	1.29×10^{-7}
DC/E14/70°C	3.14×10^{-9}	CE/E14/70°C	2.783×10^{-7}	IB/E14/70°C	9.532×10^{-7}

Table 3.Energy of activation of three starch products

Products	Samples	Energy of activation ($KJ.mol^{-1}$)	References
Dioscorea cayenensis	DC / E04	10.68	Present work
Dioscorea cayenensis	DC / E14	19.43	Present work
Colocasia esculenta	CE / E04	11.52	Present work
Colocasia esculenta	CE / E14	35.33	Present work
Ipomoea batatas	IB / E04	5.77	Present work
Ipomoea batatas	IB / E14	11.08	Present work
Round mint	/	84.79	Aghfir *et al*., 2008
Spearmint	/	62.96	Doymaz , 2006
Carrots	/	82.93	Park et *al*., 2002
Red pepper	/	28.36	Doymaz, 2006
Green pepper	/	42.80	Kaymak-Ertekin , 2002
Black tea	/	24.70	Simal *et al*.,1996
Round mint	/	406.02	Panchariya *et al*., 2002

Table 4. Results of the modeling of the kinetics of convectif drying

P produits	Echantillons	Newton			Page			Midilli			Henderson et Pabis		
		R^2	χ^2	RMSE	R^2	χ^2	RMSE	R^2	χ^2	RMSE	R^2	χ^2	RMSE
Dioscorea cayenensis	DC-P/E04/50°C	0.97293	0.00246	0.04962	0.98999	0.000833	0.02885	0.99879	0.0001048	0.01024	0.97935	0.001920	0.08643
	DC-P/E14/50°C	0.98526	0.00120	0.03466	0.99279	0.000581	0.02412	0.99413	0.0004930	0.02220	0.99017	0.000809	0.08009
	DC-P/E04/60°C	0.98567	0.00114	0.03374	0.99005	0.000755	0.02749	0.99943	0.0000543	0.00737	0.96977	0.002800	0.12901
	DC-P/E14/60°C	0.98338	0.00130	0.03600	0.99513	0.000416	0.01147	0.99926	0.0000572	0.00756	0.98691	0.000993	0.08242
	DC-P/E04/70°C	0.98694	0.00116	0.03411	0.99855	0.000129	0.03256	0.99757	0.0002170	0.01472	0.99108	0.000815	0.03340
	DC-P/E14/70°C	0.98080	0.00157	0.03965	0.96462	0.003660	0.06048	0.99094	0.0007550	0.02749	0.98968	0.000848	0.07804
Colocasia esculenta	CE-P/E04/50°C	0.98548	0.00125	0.03535	0.98558	0.001160	0.03441	0.99492	0.0004851	0.02202	0.97557	0.002250	0.06528
	CE-P/E14/50°C	0.98010	0.00157	0.03974	0.99542	0.000395	0.01989	0.98338	0.0013000	0.03600	0.98691	0.000993	0.08242
	CE-P/E04/60°C	0.98681	0.00095	0.03087	0.99562	0.000385	0.01962	0.96348	0.0034300	0.05859	0.97557	0.002250	0.06528
	CE-P/E14/60°C	0.97579	0.04608	0.02120	0.98981	0.000851	0.02917	0.99921	0.0000706	0.00840	0.99044	0.000814	0.03908
	CE-P/E04/70°C	0.99469	0.00042	0.02042	0.98723	0.000939	0.03065	0.97535	0.0019200	0.04382	0.98180	0.001620	0.05023
	CE-P/E14/70°C	0.97579	0.04608	0.00212	0.99000	0.000891	0.04554	0.99759	0.0001810	0.01344	0.98577	0.001080	0.05858
Ipomoea batatas	IB-P/E04/50°C	0.98775	0.00102	0.03200	0.98909	0.000926	0.06765	0.99871	0.0001081	0.01456	0.99149	0.000712	0.02664
	IB-P/E14/50°C	0.96779	0.00269	0.05429	0.98889	0.000948	0.05784	0.99952	0.0000290	0.00662	0.97524	0.002070	0.04824
	IB-P/E04/60°C	0.93654	0.00657	0.08265	0.99193	0.000656	0.05326	0.99168	0.0009209	0.03035	0.96358	0.003770	0.06334
	IB-P/E14/60°C	0.98244	0.00141	0.03759	0.98747	0.001010	0.05257	0.99932	0.0000389	0.01026	0.98558	0.001160	0.03441
	IB-P/E04/70°C	0.96188	0.00235	0.05308	0.98884	0.000933	0.05321	0.97535	0.0019200	0.04382	0.97043	0.002180	0.05265
	IB-P/E14/70°C	0.98074	0.00157	0.03979	0.98884	0.000933	0.05321	0.99468	0.0004528	0.02128	0.98250	0.001440	0.03799

This difference can be explained by the fact that the starch products are very rich in interstitial water, consequently, they require a weak energy necessary to start evaporation the water molecules which are there.

Modeling of the kinetics of drying

The results of numerical analysis of curves of kinetics of drying of *Dioscorea cayenensis* (DC.), *Colocasia esculenta* (EC) and *Ipomoea batatas* (IB) with the model of Newton, Page, Midilli and Henderson and Pabbis are presented in Table 4.

Do the values of criteria of modeling vary from 0.96462 = R^2 = 0.99943, of 0.000054 = χ^2 = 0.00366 and of 0.00737 = RMSE = 0.06048 during the drying of *Dioscorea cayenensis* (DC) of 0.97557 = R^2 = 0.99921 of 0.0000706 = χ^2 = 0,00225 and of 0.0084 = RMSE = 0.08242 for the drying of *Colocasia esculenta* (EC) and finally of 0.93654 = R^2 = 0.99952, of 0000029 = χ^2 = 0.00657 and of 0.00662 = RMSE = 0.08265 for *Ipomoea batatas* (IB). In a general way, the four models provided good forecasts, where the average quadratic error extended between 0.00212 and 0.08265 by using the model from Newton, between 0.01147 and 0.06765 by using the model of Page, between 0.00662 and 0.05859 by using the model of Midilli and finally between 0.02664 and 0.12901 by using the model Henderson and Pabbis.

Table 5. Evolution of the parameters of the model of Midilli with the temperature of drying

Produts	Samples	Model of Midilli		
		a	k	b
Dioscorea cayenensis	DC-P/E04/60°C	0.97452	-0.00437	-0.01148
Colocasia esculenta	CE-P/E14/60°C	1.01505	0.00869	-4.31E-04
Ipomoea batatas	IB-P/E14/50°C	1.00496	0.00394	-5.91E-04

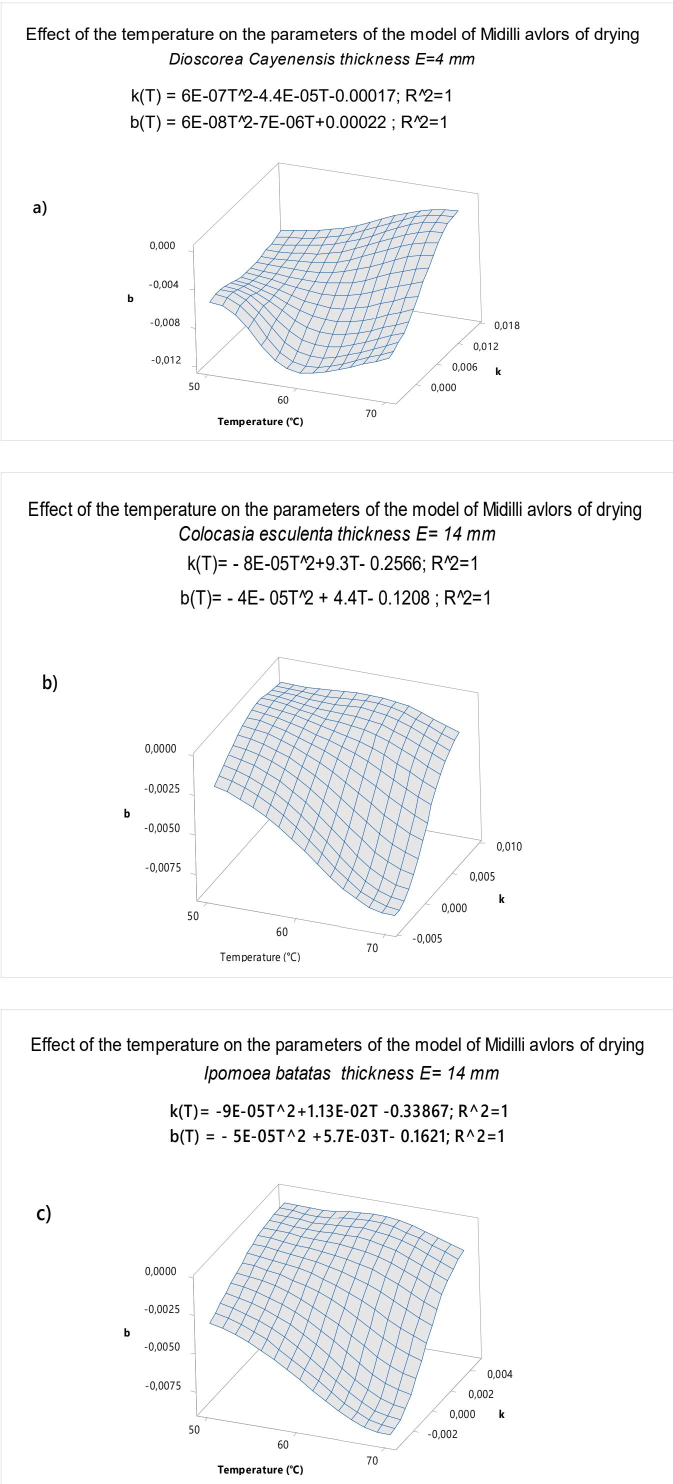

Fig.4. (a,b,c). Digramme of surface of parameters of the model of Midilli during the drying of Dioscorea cayenensis (a), Colocasia esculenta (b) and Ipomoea batatas

The smoothing of the curves of kinetics of drying shows that, the highest values of R^2 and χ^2 and the weakest RMSE obtained with the model of Midilli for all the three starch products. The best predictions with the model of Midilli during the convectif drying of *Colocasia esculenta* and *Ipomoea batatas* are obtained starting from thickness E = 14 mm, contrary has that of *Dioscorea cayenensis* which is appropriate better for the thickness E = 4 mm. The parameters of the model of Midilli of each product (Table 5) and the their evolution with the temperature of drying (Fig.4) show that, the behavior of *Colocasia esculenta* and *Ipomoea batatas* during drying are close compared to that to *Dioscorea cayenensis.* The aptitude of the model of Midilli to adjust the kinetics of drying is in conformity with that obtained by Al-Harahsheh *et al.*, 2008 and Lahmari *et al.,* 2012.

Conclusion

Drying remains one of the unit operations which necessarily intervenes in the transformation of the roots and tubers. It makes it possible to preserve the foodstuffs by the water elimination per evaporation by using like energy heat. The reduction in the water content of the product during drying makes it possible to reduce the growth potential of the micro-organisms and the undesirable chemical reactions during the storage of this one while increasing its lifespan. The results of the study of the convectif drying of *Dioscorea cayenensis, Colocasia esculenta* and *Ipomoea batatas* show that the kinetics of drying of these products proceed in two (02) phases in particular the phase of temperature setting and the phase at decreasing speed in absence of the phase at constant speed. The temperature of convectif drying to the drying oven and the thickness of the product have effects on the duration of drying and the coefficient of effective diffusion. The rise in the temperature from 50 to 70 °C makes it possible to reduce the time of drying of 14,61 % of 34,25 % and by 30 % respectively during the drying of the samples of *Dioscorea cayenensis, Colocasia esculenta* and *Ipomoea batatas* thickness 14 Misters the reduction the thickness from 4 to 14 mm increases the coefficients of diffusion of 8.0 2 $\times 10^{-10}$ with 3.14×10^{-9} m^2 s^{-1} (CD), of 4.38×10^{-8} with 2.78×10^{-7} m^2 s^{-1} (EC) and of 1.29×10^{-7} with 9.53×10^{-7} m^2 s^{-1} (IB) during convectif drying with 70°C. This reduction thickness lowers the energy barrier from 19.43 to 10.68 kJ. mol $^{-1}$ from 35.33 to 11.52 kJ. mol^{-1} and from 11.08 to 5.77 kJ. mol^{-1} respectively during the drying of *Dioscorea cayenensis Colocasia esculenta* and *Ipomoea batatas.* The model of Midilli appears to better describe the water loss during the convectif drying of these three starch products with the values of coefficient of determination R^2 close relations of 1 and those of reduced ki-square (χ^2) and of the root carr ée of the average quadratic error (RMSE) close to 0.

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