World Journal of Dairy & Food Sciences 2 (2): 83-88, 2007
ISSN 1817-308X

Influence of Pre-treatment on Drying on the Drying Kinetic of A Local Okro (*Hibiscus ersculentus*) Variety

A. Kuitche, M. Edoun and G. Takamte

Department of Automatic, Energetic and Electrical Engineering,
ENSAI, P.O. Box 455 University of Ngaoundere, Cameroon

Abstract: The present work consists is aimed at studying the influence of pre-treatment on the drying on the drying kinetic of a local Okro variety. Experiments were performed in an forced convection electric drier at an air speed of 2 m s^{-1} within the temperature range 40-55°C. The Okro sample were blanched before drying. During experimentation, the mass of the Okro sample, the ambient air temperature and relative humilities were continuously recorded. From the experimental results recorded, the curves of loss of weight with drying time were drawn. Several models were tested to model the drying kinetics. The Midilli & al. model had the highest R^2 value (99.72%), the lowest MSE and a very reduced χ^2 value. This model described best, the drying behaviour of Okro. The effective diffusivity varied from 4,462 10^{-9} to 2,941 10^{-9} m^2 s^{-1} for the non-blanched Okro samples and from 4,662 10^{-9} and 3,452 10^{-9} m^2 s^{-1} for blanched samples. The activation energy was found to be 779 Kj mol^{-1}.

Key words: Okro . drying . blanching . effective diffusivity . activation energy

INTRODUCTION

Mechanisms that govern the drying processes are complex and depend strongly on heat and mass transfer within the product. The complexity of these mechanisms is due to the coupling of these transfers during the process. In the literature, thin-layer modelling of the drying process of biological product and drying in general can be modelling of three different manners: theoretical, semi-theoretical and empirical. The mathematical modelling takes in account only internal transfer within the product while the others take in account the transfer between air and the surface of the product [1, 2]. The mathematical modelling consisted on the resolve of the general equations of drying, using either analytic method or numerical method. While considering some simplifying hypotheses [3] solved analytically the FICK's second law for various regularly of shaped bodies such as rectangular, cylindrical and spherical. The combined use of these solutions with the Arrhenius one permitted to successful predict the drying process of some product [4] for rice and [5] for rapeseed. [6] gave from numerical solutions mass and thermal transfers at the time of convective drying of the cork and found the theoretically satisfactory output. But the simulation of the drying by the numeric resolve of equations limits itself to the theoretical phase because the complexity of phenomena entering in game gives back this very difficult approach.

The semi-theoretical models generally derive from the mathematical model simplification. But the difficulty to measure the variation of the diffusion coefficient during the drying, gives back the application of this difficult model type. For grounds of simplification, it is necessary to choose a constant diffusion coefficient therefore. [7] proposes the concept of drying curve characteristic then to simplify problem [8] expresses the rate of drying according to the content in water of the product. But such an approximation doesn't constitute a physical modelling of the drying phenomenon in question [9].

The empiric modelling derives from the relation between the content in water of the product and the time of drying. In this case, the fundamental aspect of drying process is neglected because it is necessary to find a relation between the experimental values and to adjust them to curves [10-12] proposed models that can predict the behaviour of the product during the drying. These models have been used and have been adjusted satisfactorily by [13] for rice [14] for the white bean [15] for the banana, mangos and onions [16] for dates [17] for dark tea [17] for carrotses [18] for the solar drying of tomatoes and [19] for plums [20] proposed a drying model that can predict the behaviour of air during the drying of some local tropical products

Corresponding Author: Dr. A. Kuitche, Department of Automatic, Energetic and Electrical Engineering, ENSAI, P.O. Box 455, University of Ngaoundere, Cameroon

(anoint, tomatoes…). But in the literature works carrying on Okro are rare. In tropical regions, this vegetable is nowadays on the basis of the feeding of populations. Notably in the confection of gluey soup. It is why we oriented the present work on the modelling of the kinetics of drying of a local variety of Okro. During works we will study the behaviour of Okro having either treated or no and to find out the best model that can predict that can explain the behaviour of this vegetable during the drying process.

MATERIALS AND METHODS

Experimental device: The experimental device is a convective pilot dryer with controlled air circulation [20].

Measuring points on a drying tray: To the surface of a tray, 9 points were chosen to study the variability of the temperature to the surface of empties tray and of a loaded tray of product. The face 1 represents the different points of temperature measures to the surface of the tray.

The measuring system of is consisted of an electronic STATORUS balance (precision 0.001 g) for the measuring of the mass, 4 thermocouples of K type (precision 0.1°C), a wind gauge numeric Testo 405-V1 (precision 0.001 m s^{-1} /0.1°C) for the speed and the temperature of air, a temperature data logger with MIC 640 and a computer.

Experimental protocol: The vegetable used is a local variety of Okro(*Hibiscus esculentus)* commonly found on the market. The vegetable was washed in ordinary water. The washed vegetables were then cut into 1 cm thick slices. 50 slices each weighing about 20g (a total mass 1kg) were deposit on each drying tray.

The initial and final moisture content of samples were determined for each drying run using the oven method for 24hrs at 105°C [21].

Weighing was done at 30minutes intervals in order to establish the kinetics of weight of loss and deduce the evolution of the moisture as a function of time from the relation:

$$H_t(\%) = \frac{M_t}{M_s}$$

Where M_t is the mass at time t and M_s the mass of the product after oven for 24hrs at 105°C.

The air temperature was recorded after every 30 minutes by used of thermocouples which linked to a computer by the data logger.

Table 1: Drying conditions

Designation	Treatment	Drying temperature	Air speed
T1	Blanching	55°C	2m s^{-1}
T2	Blanching	50°C	
T3	Blanching	45°C	
T4	Blanching	40°C	
NT1	Not treated	55°C	
NT2	Not treated	50°C	
NT3	Not treated	45°C	
NT4	Not treated	40°C	

Table 2: List of models tested

N°	Modèle	Expression
1	Newton	MR = exp(-kt)
2	Page	MR = exp(-kt^n)
3	Henderson et Pabis	MR = a.exp(-kt)
4	Logarithmic	MR = a.exp(-kt)+c
5	Two term	MR = a.exp(-kt) + b.exp(-k_1t)
6	Diffusion approximative	MR = a.exp(-kt) + (1-a)exp(-kbt)
7	Midilli *et al.*	MR = a.exp(-kt^n) + b.t

The air speed through the loaded trays was 2 m s^{-1} and the drying temperature varied from 40-55°C.

Plant material: In this study we used local OKRO (*Hibiscus esculentus).* Table 1 shows the pre-treatments given to Okro before drying.

Table 2 regroups some semi empirical and empirical models selected from the literature to describe the drying kinetics of Okro.

The correlation is the first criteria to determine the best equation coefficient that describes drying curves. In addition the mean of standard deviation and Ki-square are used to improve the precision of curve smoothing. The Ki-square is calculated from:

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2}{N-n}$$

With $Mr_{exp,i}$ is the i-th experimental moisture content and $Mr_{pre,i}$ the i-th predicted water content, N is the number of experimental points and n the number of constant of the model used.

Blanching: Blanching, the exposure of a product to high temperatures for some few minutes is the key step in the transformation of a product into more stable from the traditional preservation methods; this heat treatment is used principally to destroy enzymes that are likely damage fruits and vegetables. Blanching equally has a role, to reduce the initial microbial charge and inactivate thermo labile micro-organisms. Blanching temperature letale to a large portion of geast, fungi and aerobic micro-organisms. It has been reported that blanching reduces microbial charge by 60-90% [22].

Blanching can carried out in very hot or boiling water as well as in saturated water vapour. This last method is preferred because it retains the sensory properties (notably the texture) and nutritional properties (especially the soluble vitamins in water) [23, 24].

RESULTS AND DISCUSSION

Evolution of water content: Given that all the Okro samples were from the same cultivar and were treated at the same period, they had almost the same water content. Figure 2 and 3 present the evolution of moisture content with time, of blanched and non-blanched Okro dried at different temperatures. From the figures, it is observed that, there is no temperature attainment phase. After 500mins (1/10 of the drying time) about 50% of the moisture was already removed from the product. The moisture content at the end of drying was about 10%, inline with the recommended of 7-12% for tropical fruits.

Drying temperature had a significant effect on the drying rate of Okro. Similar trents were observed by [20, 25-29]. Blanched Okro dried faster that non-blanched Okro (Fig. 4).

Assessment of models: The drying kinetics models were fitted to seven models selected from the literature. The correlation coefficients MSE and χ^2 were calculated for each model (Table 3 and 4). It is evident from the tables that from the R^2 values, all models were acceptable [17, 30-33].

The Midilli & al. model had the highest R^2 value (99.72%), the lowest MSE and a very reduced χ^2 value. This model described best, the drying behaviour of Okro. This model was then retained for subsequent calculations.

Coefficients of the model of Midilli *et al*.

Count of the efficient diffusivity: While considering that during the drying of Okro the phenomenon of water diffusion (matter) is dominant, the Fick's second law could be used to describe the drying of Okro slices. The resolution of this equation for the case of the spherical particles gives us:

$$HR = \frac{HR - HR_c}{HR_0 - HR_c} = \frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}\exp\left(-\frac{\pi^2 n^2 D_{eff}.t}{r^2}\right)$$

Table 3:Statistical results of the different models tested for the treated samples

Modèle	Essais	R^2	MSE	χ^2 (*10^{-4})
Newton	NT1	95.65	0.00411	0.4251
	NT2	99.01	0.00095	0.1100
	NT3	99.76	0.00021	0.0910
	NT4	99.75	0.00018	0.3100
Page	NT1	99.01	0.00096	9.1001
	NT2	99.29	0.00069	1.2581
	NT3	99.63	0.00032	1.4482
	NT4	99.70	0.00021	0.0958
Henderson et Pabis	NT1	96.98	0.00291	6.7621
	NT2	99.12	0.00079	1.6328
	NT3	99.77	0.00020	1.0010
	NT4	99.88	0.00008	0.5782
Logarithmique	NT1	99.73	0.000264	1.6284
	NT2	99.78	0.000215	1.0091
	NT3	99.84	0.000145	0.9847
	NT4	99.90	0.000072	0.5482
Two term	NT1	99.85	0.000149	0.0962
	NT2	99.16	0.000852	1.5362
	NT3	99.83	0.000156	1.0009
	NT4	99.92	0.000075	0.5482
Diffusion approximative	NT1	99.80	0.000197	1.2185
	NT2	99.78	0.000220	1.3361
	NT3	99.76	0.000210	1.2185
	NT4	99.88	0.000095	0.5782
Midilli *et al*	NT1	99.83	0.000164	0.8151
	NT2	99.77	0.000231	1.2162
	NT3	99.93	0.000600	0.2735
	NT4	99.92	0.000580	0.3361

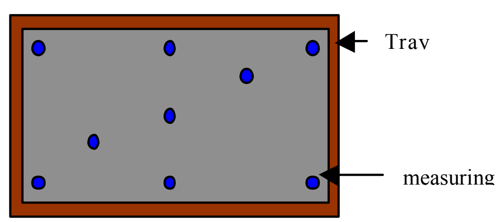

Fig. 1: Measuring point at the surface of the tray

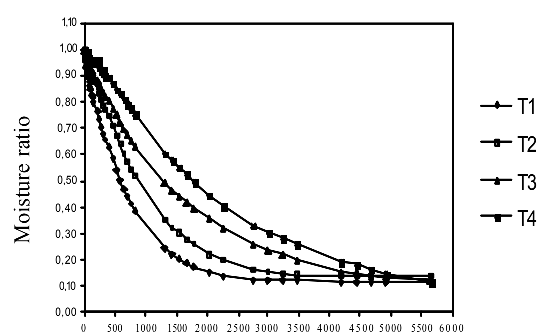

Fig. 2: Evolution of moisture content with time of blanched Okro at 55, 50, 45 and 40°C

Table 4: Statistical results of the different models tested for the not treated samples

Modèle	Essais	R^2	MSE	$\chi^2(*10^{-4})$
Newton	T1	97.87	0.00322	0.4431
	T2	98.34	0.00191	2.3121
	T3	99.35	0.00059	0.9815
	T4	99.33	0.00062	0.5654
Page	T1	98.38	0.00167	9.1250
	T2	98.51	0.00154	3.2410
	T3	99.69	0.00029	1.4423
	T4	94.65	0.00514	8.7210
Henderson et Pabis	T1	97.56	0.00250	2.5271
	T2	98.31	0.00180	6.7611
	T3	99.62	0.00036	1.6920
	T4	99.51	0.00046	1.9638
Logarithmique	T1	99.86	0.00014	0.9221
	T2	99.73	0.00291	1.9633
	T3	99.95	0.00004	0.2025
	T4	99.52	0.00046	2.2573
Two term	T1	99.90	0.00010	0.4918
	T2	99.85	0.000165	1.0000
	T3	99.61	0.000356	1.9614
	T4	99.51	0.000485	2.1621
Diffusion approximative	T1	99.32	0.000710	4.4176
	T2	99.84	0.000160	1.0000
	T3	99.91	0.000086	0.4497
	T4	99.40	0.005860	1.9645
Midilli *et al.*	T1	99.89	0.000113	0.6413
	T2	99.93	0.000077	0.3629
	T3	99.95	0.000045	0.2371
	T4	99.72	0.000273	0.4215

Where *t* is drying time, ris half radius of the Okro and D_{eff} is effective diffusivity of slices.

$$\ln\left(\frac{HR}{HR_0}\right) = \ln\left(\frac{6}{\pi^2}\right) - \left(\pi^2 \frac{D_{eff}}{r^2}.t\right)$$

can be put in the general form K.t+b = 0 and K is the gradient of

$$\ln\left(\frac{HR}{HR_{.0}}\right) = f(t)$$

Where

$$K = \frac{\pi^2 D_{eff}}{r^2}$$

D_{eff} was calculated for all the different Okro drying runs. So the efficient diffusivity of Okro slices varied between 4,462 10^{-9} and 2,941 10^{-9} m^2 s^{-1} for non-blanched slices and between 4,662 10^{-9} and

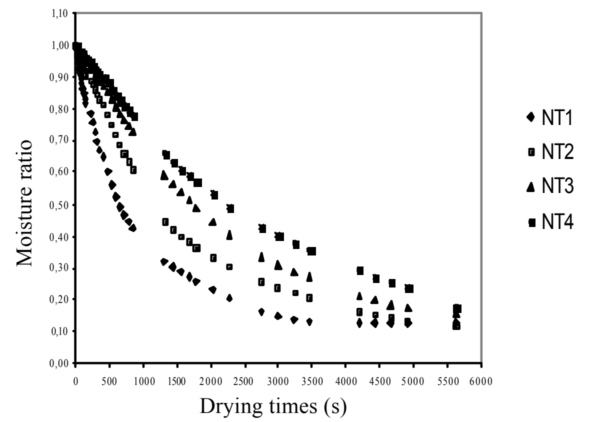

Fig. 3: Evolution of moisture content with time of non-blanched Okro at 55, 50, 45 and 40°C

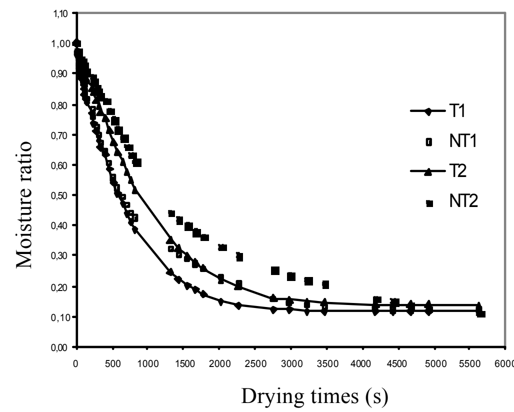

Fig. 4: Influence of blanching on the drying rate of Okro at 55 and 50°C

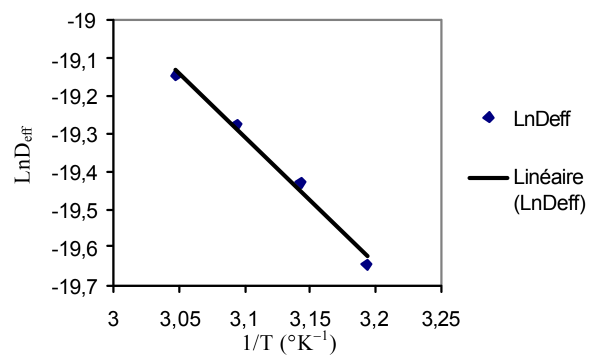

Fig. 5: Evolution of $\ln D_{eff}$ with 1/T for the different temperatures

3,452 10^{-9} m^2 s^{-1} for blanched slices. Again it is noticed that, the effective diffusivity was greater for blanched that unblanched Okro sizes.

The Works of [5, 30, 34] showed that the varied more as a function of temperature than water content. This relation is given by the equation of Arrhenius as:

Table 5: Parameters of the Midilli model and al. for Okro

Modèle	Essais	a	k	n	b	R^2	MSE
Midilli *et al.*	T1	0.9751	0.0015	0.9597	0.000024	99.89	0.000113
	T2	0.9767	0.00038	1.1000	0.000027	99.93	0.000077
	T3	0.9863	0.00057	0.9915	0.000013	99.95	0.000045
	T4	0.9947	0.000084	1.2100	0.000015	99.72	0.000273

Table 6: Parameters of the Midilli model and al. for the no-treated samples

Modèle	Essais	a	k	n	b	R^2	MSE
Midilli *et al.*	NT1	1.0073	0.003563	0.8139	0.0000197	99.83	0.000164
	NT2	0.9840	0.000437	1.0429	0.0000196	99.77	0.000231
	NT3	0.9943	0.000160	1.1265	0.0000180	99.93	0.000600
	NT4	0.9980	0.000192	10.070	0.0000115	99.92	0.000580

Table 7: values of activation energy of some products

Product	E_a (Kj mol^{-1})	Reference
Corn	27.61	[35]
Potato	20.00	[36]
Mint	82.93	[37]
Prune	57.00	[38]
Carrot	28.36	[33]
Black tea	406.02	[17]
Onion	1200.00	[39]
Paprika	2036.00	[40]
Okro	779.00	Present work

$$D_{eff} = D_0 \exp\left(-\frac{E_a}{RT}\right)$$

Where D_0 is the diffusivity coefficient at infinite temperatures and E_a the activation energy of the (Kj mol^{-1}), R the gaz constant, T temperature in °K.

Figure 5 presents $\ln(D_{eff}) = f(1/T)$ for the different temperatures. The gradient of the curves gives $E_a = 779$ Kj mol^{-1} and $D_0 = 1{,}812\ 10^{-5}$ m^2 s^{-1}

CONCLUSION

The influence of pre-treatment on the drying kinetic of a local Okro variety for were studied in the present work. From the experimental results recorded, the curves of loss of weight with drying time were drawn. Several models were tested to model the drying kinetics. The Midilli & al. model had the highest R^2 value (99.72%), the lowest MSE and a very reduced χ^2 value. This model described best, the drying behaviour of Okro. The effective diffusivity varied from 4,462 10^{-9} to 2,941 10^{-9} m^2 s^{-1} for the non-blanched Okro samples and from 4,662 10^{-9} and 3,452 10^{-9} m^2 s^{-1} for blanched samples. The activation energy was found to be 779 Kj mol^{-1}. These results we will be useful in the phase of conception of a drier adapted to this product to reduce the losses post-harvest in the tropical zones.

REFERENCES

1. Henderson, S.M., 1952. A basic concept of equilibrium moisture. Agric. Eng., pp: 29-32.
2. Fortes, Okos, 1981. Non-equilibrium thermodynamics approach to heat and mass transfer in corn. Transactions ASAE, 15: 761-769.
3. Wang, C.Y. and R.P. Singh, 1978. A single layer drying equation for rough rice. ASAE paper NO: 78-3001, ASAE, St Joseph, MI.
4. Ece, M.C. and A. Cihain, 1993. A liquid diffusion model for drying rough rice. Transactions of ASAE. 15: 156-159.
5. Crisp and Woods, 1994. The drying proprieties of rapeseed. J. Agric. Eng. Res., 57: 89-97.
9. Kapseu, Kenmogne, Broto and Roques, 2000. Aproche méthodologique de la modelisation du séchage des produits tropicaux. In séminaire international sur le séchage et la valorisation du karité et de l'aiélé. Yaoundé, Presses Universitaires, pp: 271-282.
10. Lewis, E.K., 1927. Rate of drying of solid materials, Industrie. Eng. Chem., 13: 151.
14. Hutchinson and Otten, 1983.
15. Desmorieux Hélène, 1992. Le séchage en zone subsaharienne: Une analyse à partir des réalités géographiques et humaines. Thèse de doctorat de l'Institut Polytechnique de Lorraine, Nancy, France.
16. Kechaou, N., W. Jomoa and Belghith, 1998. The caracterictic drying equation of the tunisia deglet Nour dates. Drying "98", C: 2049-2055.

17. Panchariya, P.C., D. Popovic and A.L. Sharma, 2002. Thin layer modelling of black tea drying process. J. Food Eng., 62 (3): 63-72.
18. Kamil Sacilik, Rahmi Keskin and Ahmet Konuralp, 2005. Mathematical modelling of solar tunnel drying of thin layer organic tomato. J. Food Eng., 73: 231-238.
19. Hakan Okyay Menges and Can Ertekin, 2006. Thin layer drying model treated and untreated stanley plums. Energy Conversion and Management, 47: 2337-2348.
20. Kuitche, A., M. Edoun and J. Kouam, 2005. Modélisation du profil de température dans un séchoir construit dans l'environnement tropical. Accepté pour publication. J. Food Eng., Réf. JFOE/3976.
26. Rozis Jean-François, 1995. Sécher les produits alimentaires, collection le point sur, pp: 344.
28. Lavialle, E., 1991. Incidence de la température de séchage sur l'oxydation des lipides et la coloration des cerneaux de noix. DEA de Sciences des Aliments, Université de Bordeaux I, pp: 29.
29. Edoun Marcel, 2004. Contribution à l'étude des écoulements d'air dans un séchoir: Modélisation du profil de température; mémoire de fin d'étude Ingénieurs de Maintenance Industrielle et Productique, ENSAI, Université de Ngaoundéré, Cameroun.
30. Madamba, P.S., R.H. Driscoll and K.A. Buckle, 1996. The thin layer drying characteristics of garlic slices. J. Food Eng., 29: 75-97.
31. Azzouz, Jomoa W. and Belghith, 1998. Drying kenectic equation of single layer of grapes. Drying, B: 988-996.
32. El-Sebaii, A., S. Aboul-Enein, M.R.I. Ramadan and H.G. El-Gohary, 2002. Empirical correlation for drying of some fruits and vegetable. J. Ener., 27: 845-859.
33. Ibrahim Doymaz, 2004. Convective air drying characteristics of thin layer carrots. J. Food Eng., 61: 359-364.
35. Almin, Y. and A. Fornell, 1978. Le séchage par air chaud de produits biologiques. Etude expérimentale et modélisation. Calcul d'un séchoir, Rapport EDF.
36. Bon, J., S. Simal, C. Rossello and A. Mulet, 1997. Drying characteristics of hermispherical solids. J. Food Eng., 34: 109-122.
37. Park, K., Z. Vohnikova and F.P. Vrod, 2002. Evaluation of drying parameters and desorption isotherms of garden mint leaves. J. Food Eng.
39. Mazza, G. and M. Lemaguer, 1980. Dehydratation of Onion: Some theorical and practical considerations. J. Food Technol., 15: 181-194.
40. Carbonell, J.V., F. Pinaga, V. Yusa J.L. Pena, 1986. Dehydratation of paprika and kinetics of colour degradation. J. food Eng., 5: 179-193.

Midilli, A., H. Kucuk and Z. Yapar, 2002. A new model for single-layer drying. Drying Technol., 20 (7): 1503-1513.

Moyne, C., 1985. Etablissement des courbes de séchage-courbes caractéristiques et exploitation, cahier de l'AFSIA, N° 1, EDF éditeur Moret sur loing, pp: 3-18.

Norme Afnor, 1990. Analyse de la valeur, Analyse fonctionnelle, Vocabulaire, X 50-150, Août.

Van Meel, D.A., 1957. Adiabatic convertion batch with recirculation of air. Chem. Eng. Sci., N°9: 36-44.