International Journal of Biomolecules and Biomedicine (IJBB)

INNSPUB

ISSN: 2221-1063 (Print), 2222-503X (Online)
http://www.innspub.net
Vol. 9, No. 1, p. 1-7, 2019

RESEARCH PAPER OPEN ACCESS

Characterization and the Kinetics of drying at the drying oven and with microwave oven of the *Nephelium lappaceum* seeds

C. H. Hounounou Moutombo, A. Kimbonguila, L. Matos, B. G. Elongo, C. N. Loukoula, M. L. G. Mizere, J. M. Nzikou*

CHAIRE UNESCO-ENSP, Laboratory Process Engineering, University Marien Ngouabi, Brazzaville, Congo

Key words: Kinetics of drying, Drying oven, Microwave oven, Coefficient of diffusion, Energy of activation, *Nephelium lappaceum*.

Article Published: 20 February 2019

Abstract

The objective of this work is to contribute to valorization de *Nephelium lappaceum* by the characterization of kinetics of drying of seeds of *Nephelium lappaceum*. The seeds were dehydrated until a constant mass respectively in a drying oven and a microwawe oven. The temperatures and the powers of drying are respectively: 50, 60 and 70°C and 140, 280 and 420 W. The results show that the curves of drying of seeds of *Nephelium lappaceum* do not present a phase of constant kinetics. The coefficients of diffusion vary between $2.09.10^{-8}$ to $2.98.\ 10^{-8}m^{-2}/s$ in the interval of 50°C at 70°C and between 4.83×10^{-07} at 9.04×10^{-07} m^{-8}/s for the powers going of 140 W with 420 W the relation between Arrhenius and a value of energy of activation of 16.49 kJ. mol^{-1} expressed the effect of the temperature on effective diffusivity.

***Corresponding Author:** Jean-Mathurin Nzikou ✉ nzikoumath@yahoo.com

Introduction

Nephelium lappaceum known under the name of Ramboutan is a species imported into Africa. It would be originating in Asia (Malaysia–Indonesia) (*Solis-Fuentes et al.,* 2010). The ramboutan (*Nephelium lappaceum* L) is a highly perishable fruit, characterized by one lifespan post-recolte generally lower than 15 days. Fruit nonclimacteric.

The ramboutan must be collected with optimal maturity: uniform red coloring (for the red cultivars) associated a content of soluble solids at least equal to 16%. Les seeds of *Nephelium lappaceum* represent 5-7% of the mass of the fruits and they can contain 37.1-38.9% of total lipids, 11.9-14.1% of protein, 2.8-6.6% rough fibre and 2.6- 2.9% of ash compared to the dry matter. The major components of these last are C18:1 (37.91-40.15%); C20:0 (36.14-36.77%) (Augustin *et al.,* 1988). Similar results are presented by Solis-Fuentes *et al.* (2010), on the composition and the thermal stability of natural edible grease of seeds of *Nephelium lappaceum* (Solis-Fuentes *et al.,* 2010).

In Congo, the tree of *Nephelium lappaceum* is met in the rural zones like tree of fence or delimitation of the inhabited zones. The fruits are sold in the markets and soups by the population like exotic fruit (Ngakegni-limbili, 2012). In order to preserve fruits of this seasonal product and to make them available to the consumers during all the year, they undergo specific technological treatments such as drying. Indeed, drying one of the oldest methods of conservation of food, presents a very significant aspect in the transformation of the foodstuffs (Barel, 2013). This work aims to characterize the kinetics of drying of seeds of *Nephelium lappaceum* to the drying oven and the microwave oven.

Materiel and methods

Vegetable material

The vegetable matter which was the subject of this work is consisted of seeds of *Nephelium lappaceum*. The fruits were bought in the town of Brazzaville at the total market and were more precisely stored at the ambient temperature. To separate seeds from with pulp, the fruits were fermented safe from the light during 10 days. After the shrinking of seeds of pulp, the thickness of those was measured using a slide caliper.

Drying with the drying oven

The drying of seeds of *Nephelium lappaceum* was carried out at temperatures of 50, 60 and 70°C. The seeds of *Nephelium lappaceum* were placed at drying oven (INDELAB; 0-250°C), then weighed after each five minutes (5min). Using a balance with precision of mark EXPLORER-PRO (0-210±0.0001g), the mass of seeds was followed in the course of time until this one does not vary any more between 3 successive measurements.

Oven drying with microwaves

The drying of seeds of *Nephelium lappaceum*was carried out with powers of 140, 280 and 420W. 10g of each sample were placed on the rotary table of the microwave oven (GEEPAS) and the follow-up of this one was carried out after each minute (1min) until its stabilization.

Determination of the 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.

$X = [M_h - M_s] / M_H$ (1)

X: Water content;

M_h: Mass wet sample (g);

M_s: Mass dry sample (g);

Kinetics of drying

The instantaneous speed of drying at time t is determined by the formula hereafter:

$dX/dt = [-X(t-\Delta t)-X(t)]/\Delta t$ (2)

With,

dX/dt: Speed of drying in g of eau/g of MS/sec.

X: Water content in base dries (g of eau/g of MS).

Δt: Variation of time in seconds (or in min)

Effective diffusivity (of FF

The transfer of matter during drying is controlled by internal diffusion. The second law of Fick of diffusion indicated in the equation (3), 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 seeds of *Nepheliuml appaceum* was given starting from the analytical equation of the second law of Fick, developed by Crank (1975). By supposing that the transfers are one-dimensional, 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 is given by the following equations:

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

With,

X^*: Water content reduced

X_t (g_{water} / $g^{-1}{}_{MS}$): Water content instantaneous;

X_O (g_{water} / $g^{-1}{}_{MS}$): Water content initial;

$X_{éq}$ (g_{water} / $g^{-1}{}_{MS}$): Water content with balance;

D_{eff} ($m^2.mn^{-1}$) : Coefficient of effective diffusion;

L (m): Half-thickness of the sample;

t (min): time of drying.

$Ln(X^*) = \ln(8/\pi 2) - [((\pi)^2 \times D_{eff}/4 \times l2] \times t$ (4)

The coefficient of diffusion is thus calculated starting from the bearing graph in X-coordinate the time of drying and in LnX^* ordinate.

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:

$k = [(\pi)^2 \times D_{eff}]/4L^2$ (5)

Then, $D_{eff} = (4 \times k \times L^2/ (\pi)^2$ (6)

Withk: slope

Energy of activation

The energy of activation, 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 (D_{eff}) is correlated at the temperature of drying starting from the following equation of Arrhenius (Doymaz *et al.,* 2002):

$D_{eff} = D_O^* \exp(-E_a/RT)$ (7)

$\ln D_{eff} = \ln D_O - (E_a/RT)$ (8)

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 = X + B (9)

With a slope $k_O = E_a/R$ (10)

Then $E_a = k_O * R$ (11)

D_{eff}**:** Coefficient of diffusion (m^2/s or m^2/min)

D_O: Parameter of diffusion of Arrhenius ($m^2\ s^{-2}$)

E_a: Energy of activation ($J.mole^{-1}$);

R: constant of perfect gas (8.314 $J.mole^{-1}.\ K^{-1}$)

T: absolute temperature of the draining air (K);

Results and discussion

Effect of the temperature and the power on the kinetics of drying

The effects of the temperature and the power on the kinetics of drying were noted respectively for the techniques of drying to the drying oven (Fig. 1) and the microwave oven (Fig. 2).

The analysis of these Fig.s shows that more the temperature or the power of drying increases, the time of drying decreases. One notes a reduction in the time of drying of about 10% when the temperature increases by 50°C with 60°C and about 30% while passing from 50°C with 70°C (Fig. 1).

The reduction of the time of drying is observed, for the oven drying with microwaves compared to that of the drying oven. Time drying decreases significantly with the increase in the power. The reduction of the time of drying is observed, for the oven drying with microwaves compared to that of the drying oven. Time drying decreases significantly with the increase in the power.

It decreases about 61.11% when the power increases by 140W with 280W and 83.33% while passing from 140W with 420W (Fig. 2).

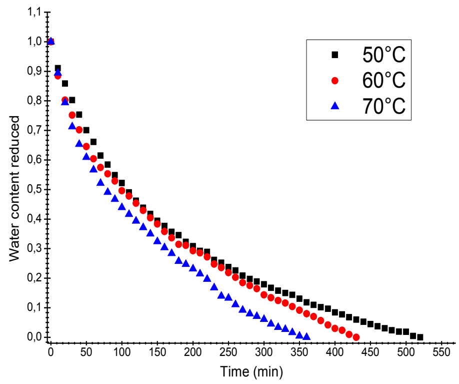

Fig. 1. Influence temperature on the kinetics of drying of seeds of *Nephellium lappaceum*.

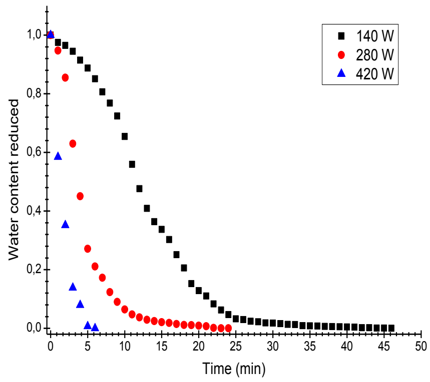

Fig. 2. Influence power on the kinetics of drying of seeds of *Nephellium lappaceum*.

Indeed for Locin (1961), the increase in the temperature and or the power of drying causes the increase in potential of exchange between the air and the product, thus supporting the fast evaporation of the water of the product, consequently a reduction in the duration of drying. This influence is due to the increase in the osmotic pressure of water inside the product which accelerates the migration of the water of the product towards outside. It is noted that at the end of drying, the speed of evaporation decreases as drying proceeds.

The influence of the temperature and the power of drying were studied by several authors (Menasra and Fahloul (2015), Arslan and Musa Ozcan (2007), Krokida *et al., (*2003) and Silou *et al.,* (1991) on the foodstuffs. The shape of the curves (Fig. 1 and Fig. 2), reflects the same pace well as that obtained by Menasra and Fahloul (2015), Arslan and Musa Ozcan (2007) and Krokida *et al., (*2003), which also worked on the foodstuffs.

The difference in time of drying observed for the two techniques of drying (with the drying oven and the furnace microwaves) can be due by the electric properties of the product which influence more technology of the microwaves. The food being insulators, they generally absorbs a great fraction of the electromagnetic one, from where them very high instantaneous heating (Mudgett, 1986).

Curves speed of drying

The evolution the speed of drying for the various temperatures and powers are presented respectively in Fig. 3 and 4. The six (06) curves speed evolve/move separately in various conditions of drying, they are very high with 70°C and 420W, followed by those from 60°C and 280W and finally weak to 50°C and 140W.

One notes that for the two techniques of drying, the curves speed present in general, two phases: a phase of temperature setting relatively short and a phase at decreasing speed. This absence of the phase at constant speed was reported in literature and was highlighted by several authors (Mujumdar, 2006; Bonazziet Bimbenet, 2003; Van Brakel, 1980), in connection with the foodstuffs and biological.

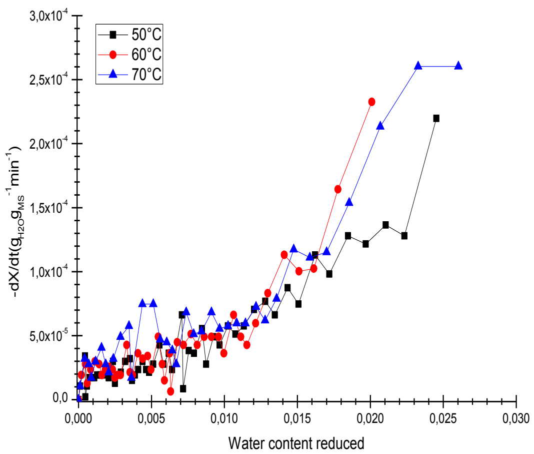

Fig. 3. Influence temperature on the speed of drying of seeds of *Nephellium lappaceum*.

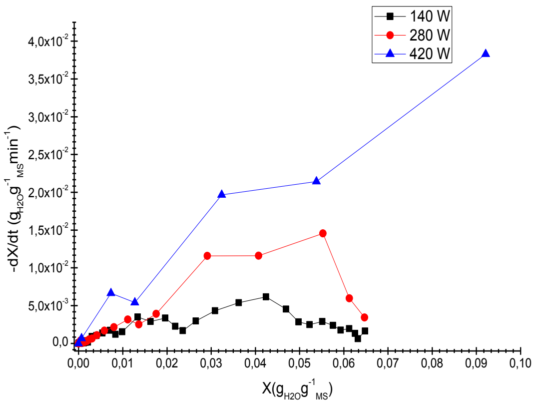

Fig. 4. Influence power on the speed of drying of seeds of *Nephellium lappaceum*.

In addition for the various powers, one notices that the phase at decreasing speed is divided into two pennies periods (Fig. 4), period at high speed and period at low speed. For Bonnazi and Bimbenet (2003), the appearance of these periods corresponds to structural changes in the product. Indeed, the deceleration the speed of drying is explained by the fact why the cellular walls disturb the fast migration of moisture towards surface external of the product, by the migration of the aqueous solutions which block the pores and by the hardening and the retraction of the surface of the product (Boughali, 2008; El Hiss, 1987).

Coefficient of diffusion

The results of the coefficient of diffusion of seeds of *Nephelium lappaceum* are presented (Table 1).

The results show that the temperature and the power have significant effects on the coefficient of diffusion. Indeed, the rise in the temperature of drying accelerates the transfer of heat and consequently the fast elimination of water in the product. Diffusivities vary from $3.48.10^{-10}$m²/mn with $4.97.10^{-10}$m2/mn for temperatures ranging between 50 and 70°C.

The variation in the temperature of drying from 50 to 70°C increases the coefficient of diffusion. Indeed, the increase in temperature involves a great agitation of the molecules and consequently, an increase in the coefficients of matter and heat transfer.

These results show that the coefficient varies primarily with the temperature and the power of drying that was illustrated by several authors (Table1). The variations of the coefficient of diffusion for temperatures ranging between 30 and 90°C were reported in the literature (Messaoudi *et al.,* 2015; Aghfir *et al*., 2008). While comparing, the results obtained with those of the literature (table 1), it should be noted that, the coefficient of diffusion varies from one product to another. It is of 2.15×10^{-8} to 1.71×10^{-7} m².s² for sheets dry of mint at the temperatures 30 = T = 50°C, of 2.58×10^{-10} to 1.72×10^{-9}m² s² for the drying of carrot of 60 to 90°C (Zielinska and Markowski, 2010 and of 3.91×10^{-10} to 6.65×10^{-10} m². s¹ for the drying of tomato of 55 to 70°C (Doymaz, 2007).

Table 1. influence temperature and the power on the coefficient of diffusion.

Products	Condition of drying	Effective diffusivity (m².s⁻¹)	References
Nephelium lappaceum	50°C	2.09×10^{-08}	Presentwork
Nephelium lappaceum	60°C	2.68×10^{-08}	Presentwork
Nephelium lappaceum	70°C	2.98×10^{-08}	Presentwork
Nephelium lappaceum	140W	4.83×10^{-07}	Presentwork
Nephelium lappaceum	280W	8.47×10^{-07}	Present work
Nephelium lappaceum	420W	9.04×10^{-07}	Present work
Carrot	60-90°C	2.58×10^{-10} -1.72×10^{-9}	Zielinska and Markowski (2010)
French bean	/	9.34×10^{-9}	Doymaz (2005a),
seeds of gombo	60 -90°C	2.58×10^{-10} - 1.72×10^{-9}	Ouoba *et al* (2010),
Kiwi	30- 90°C	3.0×10^{-10} -1.72×10^{-9}	Simal *etal.,* (2005)
Tomato	55- 70°C	3.91×10^{-10} - 6.65×10^{-10}	Doymaz (2007)

Energy of activation

The energy of activation of seeds of *Nepheliuml appaceum* was given graphically starting from the equation of Arrhenius (Fig. 5). The energy of activation makes it possible to know the influence of the temperature on the coefficient of diffusion. According to the results obtained one notes that the energy of activation increases according to the temperature. The larger the sample is, the more the need of a great energy to activate the reaction.

The energy of activation of the reaction of evaporation during drying of seeds of *Nephelium lappaceum* is of 16.49kJ. mol-1. The comparison with values already published for various products is presented in Table 2. This value makes it possible to affirm that the interaction between the water and the matrix of *Nephelium lappaceum* is weak.

Table 2. Comparison of the value of the energy of activation with those of the literature.

Products	Energy of activation Ea (kJ mol-1)	References
Nepheliuml appaceum	16.49	Presentwork
Round mint	62.96	Doymaz (2007)
Spearmint	82.93	Park *et al* (2002)
Carrots	28.36	Doymaz (2002)
Redpepper	42.8	Kaymak-Ertekin (2002)
Green pea	24.70	Simal*et al.*(2005)
Black tea	406.02	Panchariya *et al.* (2002)

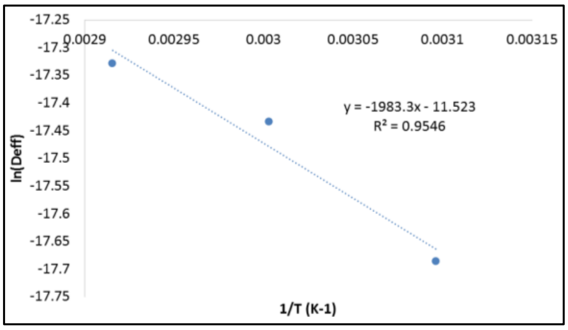

Fig. 5. Determination of coefficient of diffusion of seeds of *Nephellium lappaceum*.

Conclusion

Drying is a process which makes it possible to preserve the foodstuffs by water elimination that they contain. This reduction in the water content of the product during drying has for consequently the reduction of the growth potential of the micro-organisms and the undesirable chemical reactions during the storage of this one while increasing its lifespan. The objective of this study was to characterize, the kinetics of drying of seeds of *Nephelium lappaceum* to the drying oven and the microwawe oven at temperatures of 50, 60 and 70C and powers of 140, 280 and 420W.

The rise the temperature or in the power of drying increases the speed of dehydration and consequently reduction of the time of drying. The oven drying with microwaves made it possible significantly to reduce the time of drying compared to that observed to the drying oven. The values of the coefficient of diffusion for the various temperatures of 50 with 70C and the powers from 140 to 420W are respectively of 2.09×10^{-8} with 2.98×10^{-8} m2 S^{-1} and of 4.83×10^{-07} with 9.04×10^{-07} m2 S^{-1}.Those increase as the temperature of the air and the power increase.

The energy of activation during seed drying of *Nephelium lappaceum* is about 16,49kJ. mol under the explored conditions.

References

Aghfir A, Akkad S, Rhazi1 M, Kane CSE, Kouhila M. 2008. Determination of the diffusion coefficient and the activation energy of the mintdurin gcont inuous conductive drying, Renewable a Energy Review.

Akmel DC, Assidjo EN, Kouamé P, & Yao KB. 2009. Mathematical modelling of Sun Drying Kinetics of Thin Layer Cocoa (*Theobroma cacao*) Beans. Journal of Applied Sciences Research **5,** p. 1110-1116.

AOAC (Association of Official Analytical Chemists). 1990. Official methods of analysis (13th Ed.) Washington, D.C: Association of Official Analytical Chemists.

Arslan and Musa Ozcan. 2007**.** Evaluation of drying methods with respect to drying kinetics, mineral content and color characteristics of rosemary leaves. Energy conversion and management 2-6.

Augustin MA, Chua BC. 1988. Composition of Rambutan Seeds. Pertanika **11(2),** p.211-215

Barel M. 2013.Quality of cocoa : the impact of post-harvest treatment, know-how, Publisher Quae Paris.

Bonnazi C, Bimbinet JJ. 2003. Drying of food stuffs principles, Edition: © Engineering techniques, Agri-foodprocessing F 3000.

Boughali S, Bouchekima B, Nadir N, Mennouche D, Bouguettaia H and Bechki D. 2008. Expérience du séchage solaire dans le Sahara septentrional est algérien. Revue des Energies Renouvelables SMSTS'08 Alger **(2008),** p.105-110.

Crank J. 1975. The mathematics of diffusion (2nd Ed.) Great Britain, Clarendon Press.

Dadali G, Demirhan E, Ozbek B. 2007. Microwave Heat Treatment of Spinach: Drying Kinetics and Effective Moisture Diffusivity. Drying Technology **25,** p. 1703-1712.

Doymaz I, Mehmet P. 2002. The effects of dippingpre treatments on air-drying rates of the seed less grapes, Journal of Food Engineering, Volume **52,** p.413-417.

Doymaz I. 2005a. Drying behaviour of green beans, Journal of Food Engineering **69,** p. 161-165.

Doymaz I. 2007. Air-Drying Characteristics of Tomatoes', Journal of Food Engineering, Vol. **78,** N°4, p.1291-1297.

EL Hiss M. 1987. Modeling, identification and simulation of an agro-food solardryer, Phd thesis, University of Perpignan p.125

Gowen AA, Abu- Ghannam N, Frias J, Oliveira. 2008. Modeling dehydratation and rehydratation of cooked soybeans subjected to combinet microwave-hot-air drying. Innovative Food Science & Emerging Technologies **9,** 129-137.

Kaymak-Ertekin. 2002. Drying and Rehydrating Kinetics of Green and Red Peppers', Journal of Food Science **67,** pp. 168-175.

Krokida MK, Karathanos VT, Maroulis ZB, Marinos-Kouris D. 2003. Drying kinetics of some vegetables. Journal of Food Engineering **59(4),** 391-403.

Locin. 1961. Les opérations unitaires du génie chimique, Edition Dunod. Paris, France.

Menasra A, et Fahloul D. 2015. Contribution au séchage convectif des glandes de chêne vert d'Aurès. Inn 5ème Séminaire Maghrébin sur les Sciences et les Technologies du Séchage, Ouargla (Algérie) 33-39 p.

Messaoudi A, Fahloul D. 2015. Estimation of the mass and kinetic diffusivity of hot air drying of dates (dry variety), Inn 5th Maghreb in seminar on drying sciences and technologies, Ouargla Algeria) p. 45-62.

Mudgett RE. 1986. Electrical properties of foods, Engineering properties of foods **2,** p.389-455.

Mujumdar AS. 2006. Handbook of industrial drying. CRC Press, Florida, United States; 1308p.

Ngakegni-limbili AC. 2012. Etude de synergie des effets chimiques et biologiques des lipides de réserveset des huiles essentielles des fruits et graines saisonniers de la sous-région Afrique Centrale.

Ouoba KH, Desmorieux H, Zougmore F, et Naon B. 2010. Caractérisation du séchage convect if du gombo, influence de la découpe et de ses constituants. Afrique Sciences **06,** p37-48.

Panchariya PC, Popovic D, Sharma AL. 2002. Thin-Layer Modelling of Black Tea Drying Process, Journal of Food Engineering, Vol. **52,** N°4, p. 349-357.

Park KJZ, Vohnikova and Brod FPR. 2002. Evaluation of Drying Parameters and Desorption Isotherms of Garden Mint Leaves (*Mentha crispa*. L). Journal of Food Engineering, Vol. **51,** pp. 193-199.