ORIGINAL PAPER

MODELING OF THE DRYING KINETICS OF *MYRTUS COMMUNIS L.*

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Abstract. *This study is aimed at determining the drying speed of Myrtus communis L. by fluidization according to parameters of influence. It is based on exploiting the results of previous experimental studies, as well as the similarity between drying kinetic and chemical kinetic in order to establish a universal model. The considered parameters are: drying air temperature Tp, product absolute humidity Ns and drying air speed va.*

Keywords: *Model, Drying speed by fluidization, drying kinetic, Myrtus communis L.*

1. INTRODUCTION

The water content of aromatic and medicinal plants (WFP) constitutes the first factor influencing their conservation during storage [1]. These points out the importance of drying in the conservation of these agricultural products with great interest.

It was in this spirit that saw the light this work that aims to establish a simple and reliable model in order to characterize the drying speed of the myrtle, plant known for its multiple applications in pharmaceutical, cosmetics and agri-food industries [2].

The improvement of drying effectiveness requires the control of heat transfers that governs the product behavior during drying.

The aim of this study is to model the drying kinetic based on the similarity between chemical kinetic and drying kinetic [3]. The drying speed of myrtle by fluidization is determined under various operative conditions. The considered parameters are the drying air temperature, the product absolute humidity and the drying air speed. The analysis of these parameters influence on the drying speed and the determination of the model constants are based on obtained experimental results.

2. MATHEMATICAL MODEL

This model is established on the basis of the similarity between chemical kinetic and drying kinetic.

Knowing that the myrtle is a hygroscopic product and admitting that water transfer during its drying process is made by capillarity [4], it becomes obvious that the capillary theory for the drying with decreasing speed is the suited theory to apply.

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$$dN_s/dt = -k.(N_s-N_{se}) \qquad (1)$$

$$|dN_s/dt| = k.(N_s-N_{se})$$

In chemical kinetic, the law of Arrhenius [5] is used to describe speed variation of a chemical reaction as a function of temperature (2).

$$k = k_0.\exp(-E_a/R.T_p) \qquad (2)$$

- k, speed coefficient (or speed constant);
- T, temperature in K (kelvin);
- R, perfect gas constant ($R = 8{,}314\ J.mol^{-1}.K^{-1}$; precise value $R = 8{,}314472\ Pa.m^3.K^{-1}.mol^{-1}$);
- Ea activation energy of Arrhenius given in J.mol-1 (joule per mole).

In addition, the speed of reaction can also be expressed by the successive multiplication of chemical entities concentrations [6]. By analogy, the relation (3) expresses the drying speed as a function of the main parameters influencing it.

$$|dN_s/dt| = E(T_p).H(v_a).F(N_s) \qquad (3)$$

From (1) and (2), we obtain:

$$E(T_p).H(v_a).F(N_s) = k\ (N_s-N_{se}) \qquad (4)$$

- E(Tp) represents the influence of the product temperature on the drying speed constant.

Whilst keeping constant the other parameters (V_a and N_s), we obtain based on the law of Arrhenius:

$$E(T_p) = \exp\ (-a/T_p – b) \qquad (5)$$

$H(V_a)$ is the influence of air speed on the drying speed constant :

$$H(V_a) = \exp\ (c.V_a + d) \qquad (6)$$

Thus, from the equations (4), (5) and (6), F(Ns) which represent the influence of the product humidity level on the constant of drying speed is written as follows:

$$F(Ns) = \alpha.(N_s - N_{se}) \qquad (7)$$

From (4), (5), (6) et (7), we conclude:

$$k = \alpha.\exp(-a/T_p - b + c.V_a + d) = \exp\ (-a/T_p + c.V_a - b + d + \ln\alpha)$$

Coefficients a, b, c, d and α are calculated using the linear regression method [7].

3. MATERIALS AND METHODS

3.1. EXPERIMENTAL DEVICE

The myrtle drying is carried out within a pilot installation for fluidised bed drying (Deltalab-France) that provides drying air under controlled aerothermal conditions.

The air flow is adjusted by a speed driver controlling the motor of the fan thanks to a potentiometer. Air speed produced is measured and regulated using an anemometer probe. The input temperature of the air flow controls the heater resistance. The fluidized bed is supported by a stainless steel frame with aluminum nuts. The distributor is characterized by a drilling of 1.5mm to 3.5mm (triangular mesh).

3.2. EXPERIMENTAL PROTOCOL

Speed and air temperature are fixed at each test. Mass loss of the product is monitored by measuring its mass mti every 10 minutes at the beginning of the experimentation, and every 20 minutes after the first 100 minutes. The mass of the product is measured at the time of leaving the dryer mti at instant ti. The drying experience is interrupted if the mass of the product becomes stable at a constant value ms. Therefore, for each test, table 1 is to be filled in.

Table 1. Mass loss monitoring as a function of time

Test n°							
t_i	0	10	20	20	30	…	t_s
m_{ti}	m_0	m_1	m_2	m_3	m_4	…	m_s
$m_{ei} = m_{ti} - m_s$							
$N_{si} = m_{ei}/m_s$							

Water content at every instant t_i is calculated according to the following relation:

$$N_{s\,ti} = (m_{ti} - m_s) / m_s$$

3.3. OPERATING CONDITIONS OF DRYING

Five tests were carried out with the purpose of investigating the influence of considered parameters on the drying speed of the Myrtle and drawing thereafter needed curves for determining the established model coefficients.

Tests 1, 2 and 3 are performed at different temperatures of the drying air, while maintaining the air speed constant. Temperature values have been chosen so that they don’t affect Myrtle properties [8-10]. These three tests will make it possible to study the influence of the drying air temperature on the Myrtle drying speed.

On the other hand, tests 3, 4 and 5 are carried out at the same temperature in order to analyse the influence of drying air speed on drying kinetic.

Drying operating conditions comply with the different tests. Table 2 represents the various values of the studied parameters for each test.

Table 2. The drying operating conditions.

Test	T_a (°C)	V_a (m/s)	m_i (g)	t_s (min)
1	40	1	20	280
2	50	1	20	140
3	60	1	20	100
4	60	0.8	20	220
5	60	0.3	20	420

4. RESULTS AND DISCUSSIONS:

4.1. EXPERIMENTAL RESULTS

Fig. 1 shows the water content variation of the product as a function of time, as well as the influence of drying air temperature on drying kinetic.

During drying in tests 1, 2 and 3, water content of the product decreases and tends towards 0. The drying speed increases as the drying air temperature becomes higher.

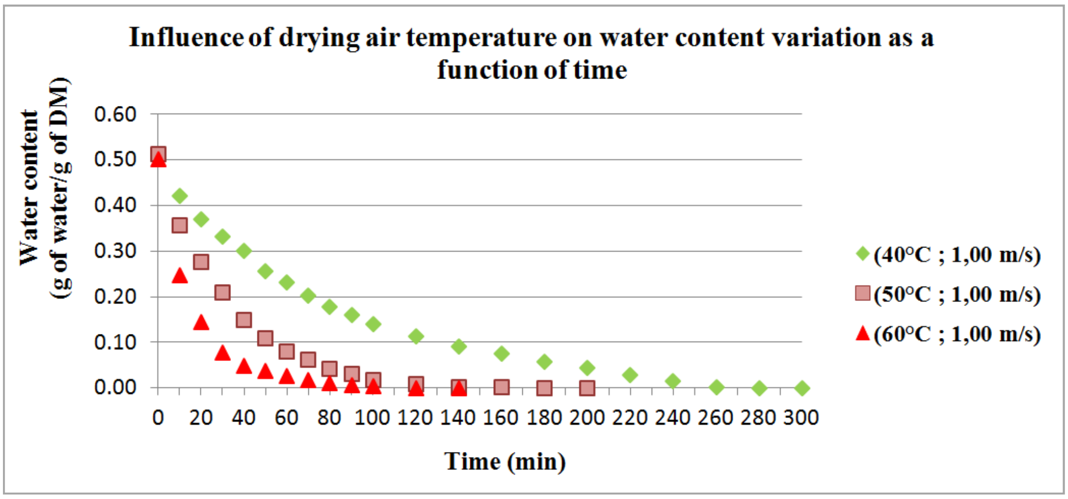

Figure 1. Influence of drying air temperature on water content variation as a function of time.

Figure 2 shows that the drying speed increases as the drying air speed becomes higher.

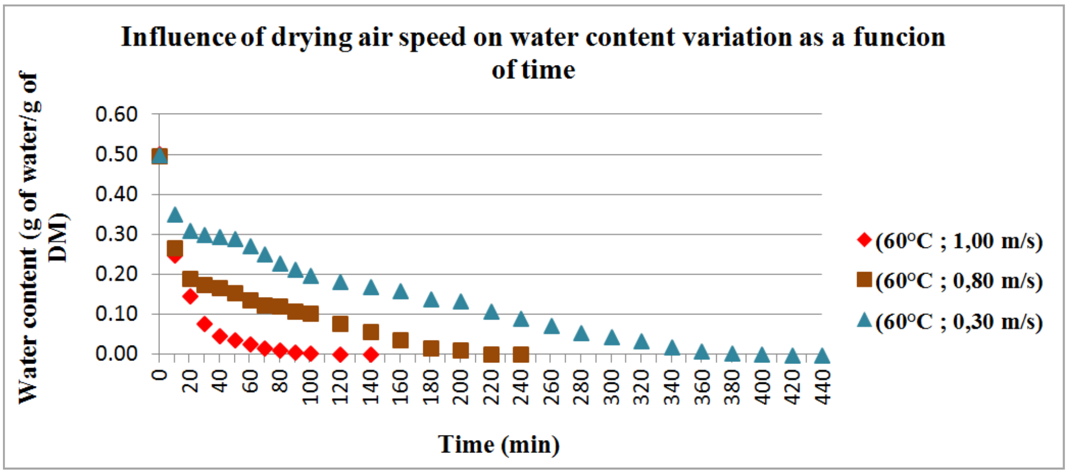

Figure 2. Influence of drying air speed on water content variation as a function of time.

Figure 3 provides the myrtle drying curves for different combinations of temperatures and drying air speeds.

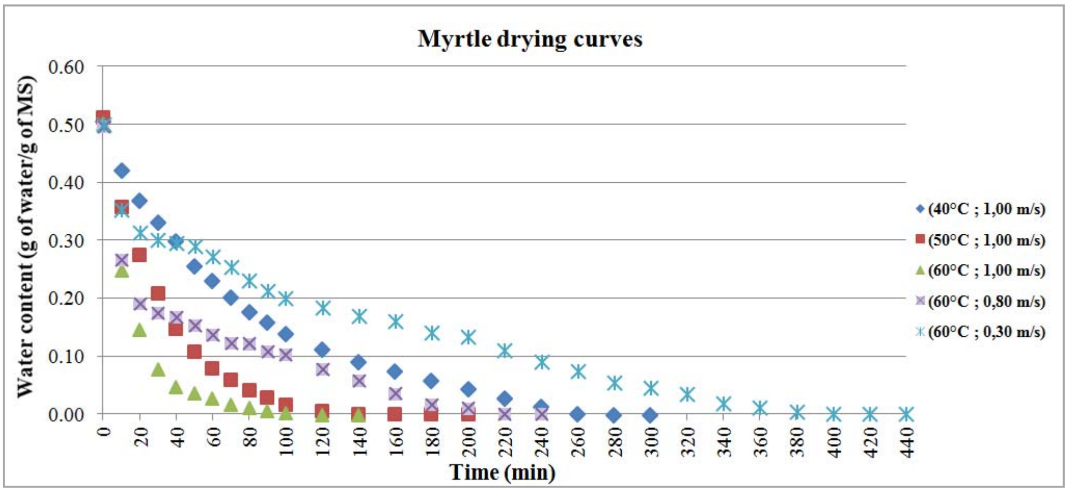

Figure 3. Myrtle drying curves.

4.2. RESULTS TREATMENT

This part is dedicated to determining the mathematical model constants (a, b, c, d, α).

4.2.1. Determination of the coefficients a and b

Tests 1, 2 and 3 have been performed in order to study the influence of the product temperature on drying speed. This temperature is considered equal to drying air. With a steady drying air, we have:

$$|dN_s/dt| = E(T_p) = \exp(-a/T_p - b)$$

$$-\ln(|dN/dt|) = a/T_p + b$$

The following graphical representation shows ln (|dN/dt|) as a function of inverse product temperature $1/T_p$. It is evident the importance of this parameter influence (product temperature) on the constant of drying.

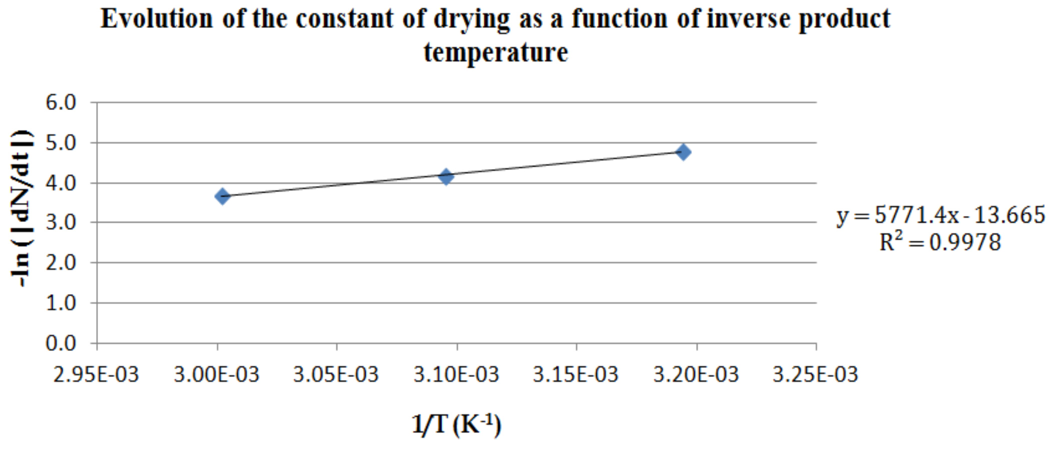

Figure 4. Evolution of the constant of drying as a function of inverse product temperature.

Drying of the myrtle obeys then the law of Arrhenius, and the coefficients a and b are calculated by linear regression: $y = 5771{,}4x - 13{,}665$; $R^2 = 0{,}9978$

Table 3. Numerical value of the coefficients a and b.

a	b
5771,4	- 13,665

4.2.2. Determination of the coefficients c and d

Fig. 6 illustrates the evolution of the constant of drying as a function of drying air speed. It is notable that the influence is very significant. With a steady temperature of drying air, we have:

$$|dN_s/dt| = H(V_a) = \exp(c.V_a + d)$$

$$\ln(|dN/dt|) = c.V_a + d$$

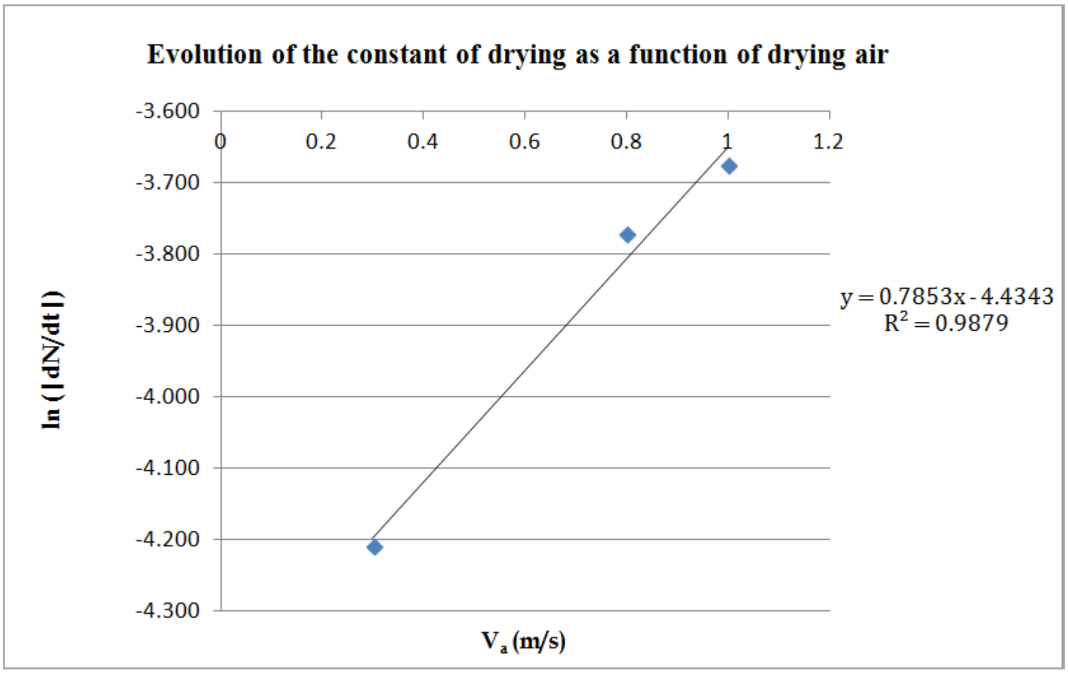

Figure 5. Evolution of the constant of drying as a function of drying air.

Numerical values obtained by linear regression for the coefficients c and d are shown in table 4: $y = 0{,}7853x - 4{,}4343$; $R^2 = 0{,}9879$

Table 4: Numerical values of c and d

c	d
0,7853	-4,4343

4.2.3. Determination of the coefficient α

The figure below shows the drying speed as a function of water content of myrtle, for the three considered temperature values in this study. These curves can be assimilated to linear curves according to the following relation:

$$|dN_s/dt| = F(N_s) = \alpha.(N_s - N_{se})$$

Numerical values calculated by linear regression for the coefficient α are shown in table 5:

Table 5: Numerical values of α

	Test 1	Test 2	Test 3	Average
α (min $^{-1}$)	0,0146	0,0371	0,0989	0.0502

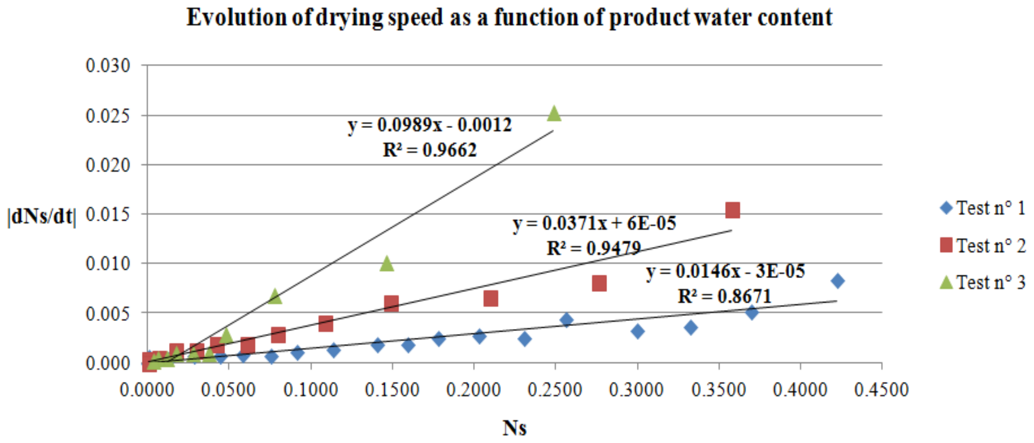

Figure 6: Evolution of drying speed as a function of product water content

5. CONCLUSION

Analysis of temperature and drying air speed effects on drying speed, led us to the conclusion that the drying is faster as the speed and the temperature of drying air increases. In addition, a model has been established representing the relation between myrtle drying speed by fluidisation and main drying parameters, such as: drying temperature, product absolute humidity and drying air speed.

The formula obtained is the following:

$$|dNs/dt| = \exp(-a/Tp + c.Va - b + d + \ln\alpha) . (Ns-Nse)$$

where: $a = 5771,4$; $b = - 13,665$; $c = 0,7853$; $d = - 4,4343$; $\alpha = 0.0502$ min -1

The results reveal that the myrtle is a hygroscopic product and its water transfer is of capillary origin.

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