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Effect of convective drying of Myrtus Communis on the yield and quality of essential oils

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Abstract

Myrtus Communis has been used as medicinal and aromatic plant and used extensively in food, cosmetic and pharmaceutical industries for the production of spice and essential oils. In order to preserve this seasonal plant and make it available to consumers during the whole year, it undergoes specific technological treatments such as drying. The objective of this paper is to determine the isotherms of adsorption and desorption isotherms and the drying kinetics of Myrtus Communis. Moisture equilibrium data were determined by using the gravimetric method with water activity ranging from 5% to 95% and three temperatures of 30, 40 and 50°C. Five mathematical models were used to fit the experimental data of sorption isotherms. The Chung-Pfost was found to be the most suitable model for describing the sorption curves. Another experimental study is devoted to the determination of the kinetics of drying under controllable conditions of temperature and moisture and to determine the influence of the drying on the yield and the quality of essential oils.

Keywords: Drying, Myrtus Communis, adsorption, desorption, modeling.

1. Introduction

The quality of most aromatic and medicinal plants preserved by drying depends to a great extent upon their chemical and microbiological stability.

The stability is a consequence of the relationship between the equilibrium moisture of the product and its correspondence water activity, a_w, at a given temperature. So, the objective of drying of aromatic and medicinal plants is to reduce their water activity and to ensure their conservation [1].

The determination of sorption isotherms of leaves of Myrtus communis is an essential step in the study of the drying and preservation, because it determines the moisture balance. It provides valuable information on the equilibrium moisture of the product. The first objective in this study is to determine experimentally the isotherms of adsorption and desorption.

The second is devoted to obtaining the drying kinetics of Myrtus communis in conditions aerothermal controlled temperature and humidity of drying air and to study the effect of the drying on the yield and quality of essential oil.

2. Determination of adsorption-desorption isotherms

2.1. Material and method

In the present work, we use saturated salt solutions in a static method. It has the advantage of presenting a more restricted domain of the water content variation.

The experimental apparatus consists of eleven glass jars each with insulated lid. Ecery glass jars is filled to quarter depth with saturated salt solution (KOH, $MgC1_2$, K_2CO_3, $NaNO_3$, KCl et $BaCl_2$) (Greenpan, 1977), so as to have a relative humidity which varies from 5% to 97%. For the desorption process, the sample of fresh Myrtus Communis leaves are putten in the sample holder. But, for the adsorption process, Myrtus Communis is deshydrated in an oven regulated at temperature of 50°C until reaching maximum dehydration. The sample is weighted every four days in order to determine their water content X_{eq}. As soon as the masses of sample become stationary, M_w, the experiment is stopped and the sample are weighted and placed in an oven whose the temperature is fixed at 105°C. The objective of this operation is to determine the dry masses of sample M_d. The moisture content X_{eq} of the product at hygroscopic equilibrium is calculated by:

$$X_{eq} = \frac{M_w - M_d}{M_d} \qquad (1)$$

The same operation is repeated for both adsorption and desorption processes at temperature 30, 40 and 50°C.

2.2. Results and discussion

The hygroscopic equilibrium of myrtus communis is determinated in 15 days for adsorption and 20 days desorption.

The results of these experiments are presented in Figures 1, 2 and 3 at different temperature.
These isotherms have the same profile for many food materials in the literature [3, 4, 5, 6, 7and 8].

These figures show that the equilibrium moisture content increases with decreasing temperature at constant relative humidity.

And yet, one can notice that the adsorption curve does not overlap with the desorption curve showing a hysteresis phenomenon. Several studies in the literature are suggested to explain this phenomenon.

They showed that the hysteresis is due to the fact that the deformation of the body during their dehydration is not going so elastic [4, 9].

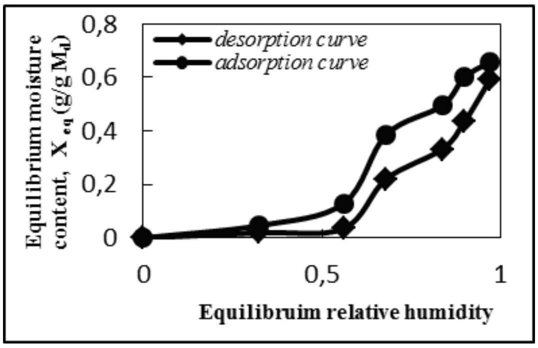

Figure 1. Isotherm of adsorption and desorption of Myrtus communis for T=30°C.

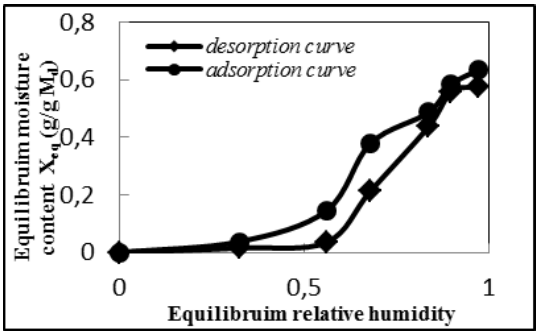

Figure 2. Isotherm of adsorption and desorption of Myrtus Communis for T=40°C.

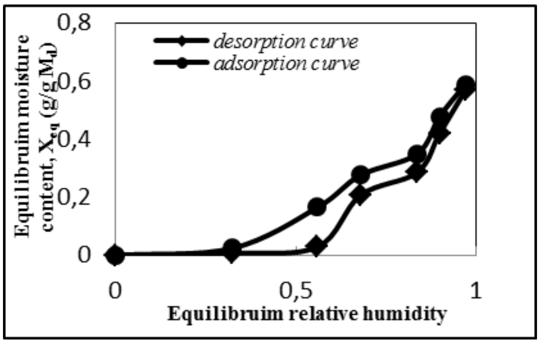

Figure 3. Isotherm of adsorption and desorption of Myrtus Communis for T=50°C.

2.3. Modeling of the adsorption and desorption isotherms

Many models have been proposed in the literature for the adsorption and desorption isotherms [10].

In this present study, we use Chung-Pfost, BET, Henderson, Oswin, Smith…to describe the relationship between the equilibrium moisture content data and the relative humidity.

The Chung Pfost model presents the advantage of perfectly describing the isotherms of desorption and adsorption for values of HR less than 0.90.

The equation expressing this model is given below [11]:

$$Ln(a_w) = -\frac{C_1}{RT} \times \exp(-C_2 . X_{eq}) \qquad (2)$$

The different coefficients and the standard error are shown in Table 2.

Table 2.

The coefficients of the selected models and the standard error for Myrtus Communis.

	Adsorption			Desorption		
	30°C	40°C	50°C	30°C	40°C	50°C
C1	0.168	0.174	0.156	0.284	0.196	0.167
C2	0.087	0.122	0.084	0.118	0.024	0.008
E (%)	0.8	3.7	0.7	1.6	3.2	0.9

According to this error E, the Chung-Pfost model describes well the isotherms.

3. Drying kinetics of Myrtus Communis equipment

The experimental device for studying the kinetics of drying tunnel is a controlled atmosphere that we have equipped with the appropriate measuring instruments.

This is a wind tunnel where you can control the temperature, velocity and humidity.

3.1. Description of experimental apparatus

The different experiments undertaken consist of styding kinetics of Myrtus Communis in a drying tunnel working by a forced convection in a controlled atmosphere (velocity, humidity and temperature).

The experimental apparatus (Fig 4) is a laboratory drying tunnel which includes:

- A treatment air unit with a variable air velocity. This parameter is measured using a velocimeter.
- Four heating battery of 3 kW installed power, regulated by a temperature probe.
- A water humidifier supplied by water at variable temperature by the intermediary of a vaporizer.

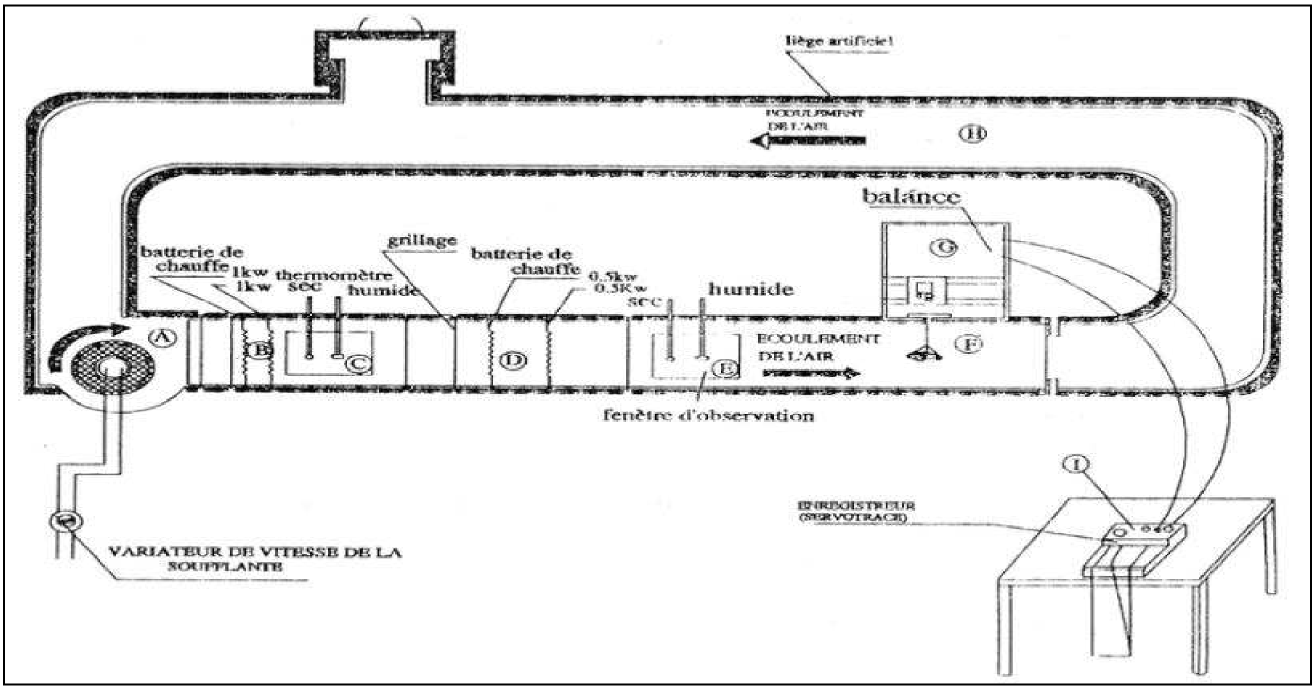

Figure 4. Experimental apparatus of drying tunnel.

3.2. Experimental Protocal

After fixation of different experimental conditions, the products to be dried are placed on a support grid and traversed by hot air. When the mass of plant becomes constant, we stopped the operation. Knowing the wet mass, the dry mass is obtained by putting the plant at the end of every experiment in an oven regulated at 105°C until dewatering completely the product.

3.3. Results and discussion

Influence of temperature : Figure 4 show that the moisture content Xeq of the product of Myrtus Communis decreases when the temperature of the drying air increases. From these results, we note the absence of phase 0 and phase 1, there is only the presence of the falling rate period (phase 2). This result is compatible with the drying literature [8, 9].

This decrease is explained by the fact that at the beginning of drying, evaporation of water from the surface of the product does not require a lot of energy, against the diffusion of water from the interior part of product to the surface requires much time.

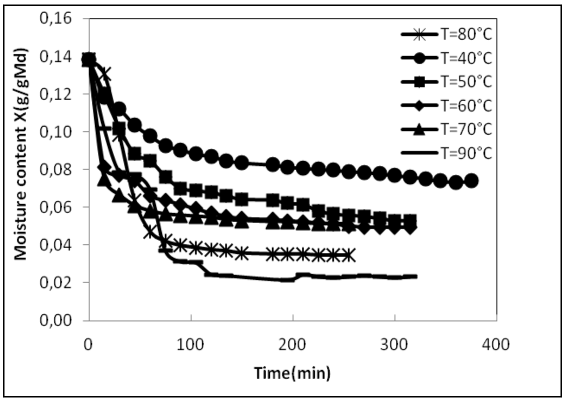

Figure 5. Influence of drying air temperature on the evolution of water content as a function of time.

Influence of humidity : In this section, we varied the humidity of the drying air by injecting a certain amount of steam down the wind tunnel. The initial water content of the product is equal to 0.23 g/g of dry mass sample. In this work, we present the results obtained at T = 70 °C for the other temperatures show no special behavior to that obtained at 70 ° C.

Figure 6 shows the evolution of water content during drying to the relative humidity used. This figure demonstrates the presence of the declining phase during the drying process. These results are consistent with other work [7].

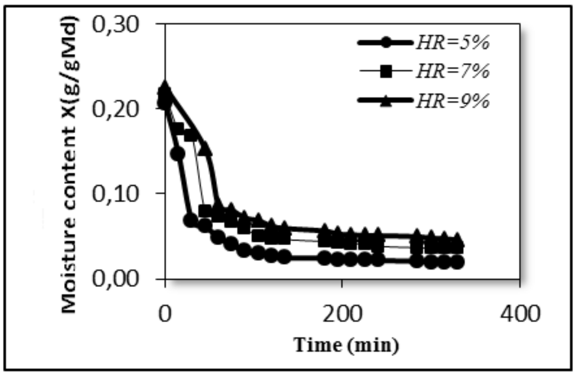

Figure 6. Influence of drying air humidity on the evolution of water content as a function of time.

4. Determination of extraction efficiency and quality of essential oil

In this section, we will study the influence of drying temperature on the efficiency and quality of essential oils. The quality of essential oils was followed by determining their chemical composition using gas chromatography coupled with mass spectrometry (GC / MS).

4.1. Extraction efficiency of essential oil

The Myrtus Communis was submitted to hydrodistillation with a clevenger-type apparatus according to the European Pharmacopoeia and extracted with water for three hours (until no more essential oil was obtained [12].

Vapor condensation obtained by hydrodistillation led to two phases:

- An aqueous phase also called aromatic water.
- An organic phase which is added sodium sulfate Na2SO4 to remove traces of water. This phase is called essential oil.

The extraction yields of essential oils are defined as follows:

$$\%\eta_{org} = \frac{\text{Mass of essential oils in the organic phase}}{\text{Dry masses of sample}} \times 100 \qquad (3)$$

$$\%\eta_{aq} = \frac{\text{Mass of essential oils in the aqueous phase}}{\text{Dry masses of sample}} \times 100 \qquad (4)$$

$$\%\ \eta_{Tot} = \%\ \eta_{aq} + \%\ \eta_{org} \qquad (5)$$

$\%\ \eta_{HEorg}$: efficiency of essential oils organic phase.
$\%\ \eta_{HEaq}$: efficiency of essential oils aqueous phase.
$\%\ \eta_{HE}$: Total efficiency of essential oils.

The results obtained show that the extraction efficiency varies considerably with temperature drying in the tunnel; it seems that the best efficiency was obtained at a temperature of 80 ° C. These results can be explained by the fact that for too high temperature, it can cause evaporation of some volatile compounds of essential oils from Myrtle so reducing the extraction efficiency. The drying tunnel is a very effective method for drying products: we noticed the speed and very good extraction efficiency for an optimum temperature equal to 80 ° C.

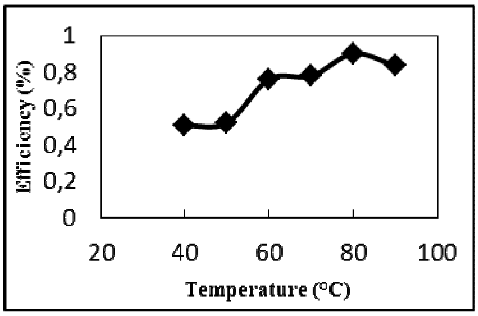

Figure 7. Influence of drying temperature on extraction efficiency of essential oils of myrtle.

4.2. Quality of essential oils

Essential oils are very complex natural mixtures which can contain about 20–60 components at quite different concentrations. They are characterized by two or three major components at fairly high concentrations compared to others components present in trace amounts.

Analysis of Essential Oil obtained after hydrodistillation was done using Gas chromatography Mass Spectrometer method [13]. The analysis shows the composition of the oil and also the percentage of each component.

Taking into account the major compounds identified in the essential oil of Myrtus Communis that we analyzed in the present study.

Table 2 presented a comparison between composition of essential oil before and after drying. This analysis has shown that the major components of the essential oil are α-pinene, 1,8 cineole, limonene, Para-cymene.

we note that the composition of the major compounds of the essential oil are degraded after drying.

The increasing of the temperature of drying wind tunnel caused the decrease of the compounds detected. It further notes that the levels of compounds such as: α-pinene (major compound) and 1.8 cineole have experienced a decrease. However, the content of other compounds such as limonene disappeared at the temperature of 60°C.

So we can conclude that the optimum temperature for best quality of essential oils is 40 ° C.

Table 2:

Comparison of essential oil components of Myrtus Communis before and after drying.

Major compounds	Composition (%)			
	Fresh leaves	T=40°C	T=50°C	T=60°C
α-pinene	19.80	20.44	10.38	5.14
1.8 cineole	38.42	18.77	7.21	0.78
limonene	13.27	11.79	2.89	6.44
Para-Cyméne	-	2.88	0.48	-

5. Conclusion

The equilibrium moisture content of Myrtus Communis leaves at four temperatures and relative humidities were determined. These curves can be prescient about the behavior of the product during (conservation and storage) to avoid changes in chemical and biological characteristics of essential oils.

From the results, it is concluded that the adsorption and desorption isotherms of medicinal plants can be measured by a gravimetric static method for different temperatures (30, 40 and 50 °C). The experimental data were used to determine the best model for predicting the adsorption and desorption isotherms of dried Myrtus Communis leaves for known levels of temperature and relative humidity. Mathematical models that best fitted the experimental data were found by statistical analysis of the experimental data: the Chung–Pfost model for adsorption and desorption isotherms. The equilibrium moisture content was higher for desorption data than for adsorption data, presenting the typical hysteresis effect commonly observed for biological materials.

The experimental study of the kinetics of drying of this product showed the influence of different parameters of the air drying on the yield and the quality of essential oils.

Acknowledgments

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Nomenclature

A, B	Chung-Pfost constant
a, b, k, n	Drying model constants
E	Mean relative error
HR	Air moisture content (%)
Md	Mass of dry matter (g)
Mw	Mass of wet matter (g)
MR	Moisture ratio
X	Water content (g/g)
X0	Initial water content (g/g)
Xeq	Equilibrium water content (g/g)
t	Time (min)

References

[1] M.Kouhila, A.Belghit and M.Daguenet, Approche expérimentale des courbes de sorption de la Menthe en vue d'un séchage par énergie solaire, Revue générale de thermique, (1999), vol.2, pp.61-68.

[2] L.Greenpan, Humidity fixed points of binary saturated aqueous soultions, Journal of research of national bureau of standards, (1977), vol.81, pp. 89-96.

[3] M.Kouhila, A.Belghit et M.Daguenet, Approche expérimentale des courbes de sorption de la Menthe en vue d'un séchage par énergie solaire, Revue générale de thermique, (1999) vol. 2, pp.61-68.

[4] M.Kouhila, A.Belghit et M.Daguenet, "Détermination expérimentale et théorique des courbes de sorption et de la cinétique de séchage de la menthe verte", Revue Française Entropie, (2001), vol 37, pp.20-3.

[5] S. K.Bag, P.Srivastav et H. N.Mishra, "Desorption and adsorption characteristics of bael pulp and powder", International Food Research Journal, (2009), vol.16, pp. 561-569.

[6] J.J.Bimbenet, Le séchage dans les industries agricoles et alimentaires, 4émes cahier du Génie Industriel Alimentaire, 1978.

[7] N.Kechaou, B.Hadrich, K.Dahak et N.Abdenouri, Etude de séchage des feuilles de bigaradier , Revue des Energies Renouvelables, (2008) ,pp.145-149.

[8] B.Touati, Etude théorique et expérimentale du séchage solaire des feuilles de la menthe verte, Thèse, Institut National des Sciences Appliquées de Lyon, (2004).

[9] A.H. Al-Muhtaseb, W.A. Mc Minn and T.R. Magee, Moisture sorption isotherm characteristics of food products: A review, Institution of Chemical Engineers, Trans IChemE 2002, 80.

[10] S. Lahsasni, M. Kouhila, M. Mahrouz and N. Kechaou, Experimental Study and Modelling of Adsorption and Desorption Isotherms of Prickly Pear Peel (Opuntia ficus indica) , Journal of Food Engineering,(2002), Vol. 55, pp. 201 - 207.

[11] S.Janjaii, K.Tohsing and B.K. Bala, Moisture sorption isotherms of Lincheu Mushroom (Ganoderma lucidum), Journal of Food Sci. Technol, Res, (2007), vol 4, pp. 315-320.

[12] [12] M.Lucchesi, Extraction Sans Solvant Assistée par Micro-ondes Conception et Application à l’extraction des huiles essentielles , Thèse, (2005).

[13] S.Zrira, B. Benjilali and G. Lamaty, Effet du séchage à l’air libre des feuilles d’E.camaldulensis sur le rendement et la composition de l’huile essentielle , Actes Ins. Agron. Vet, (1995), vol 15, pp. 27-35.